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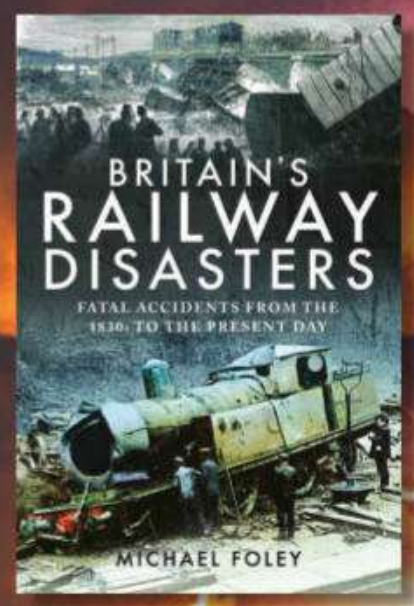

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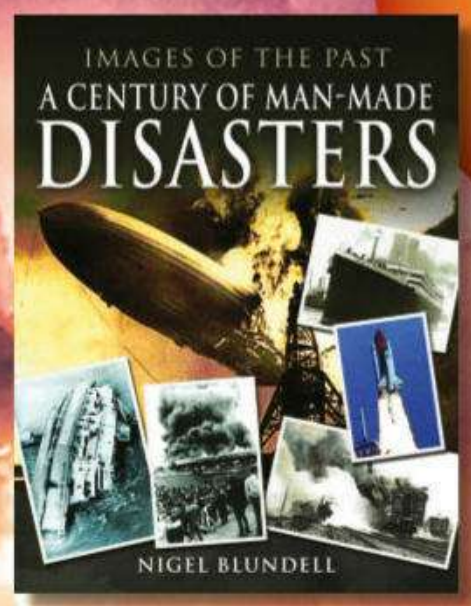

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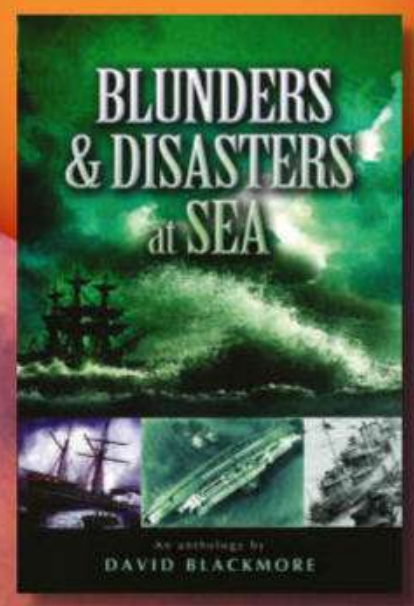

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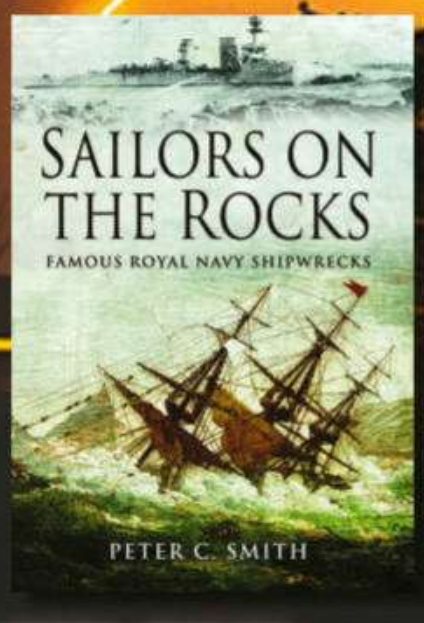

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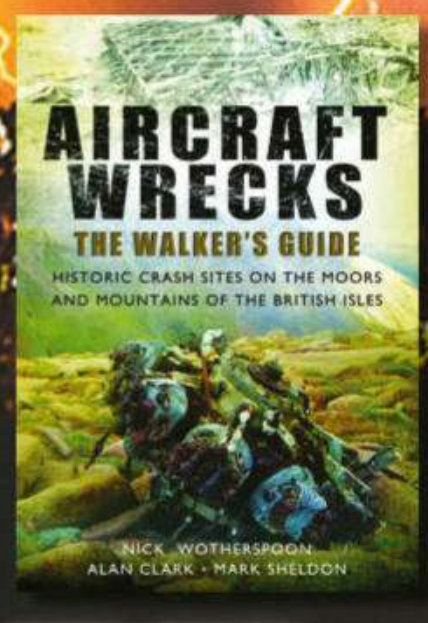

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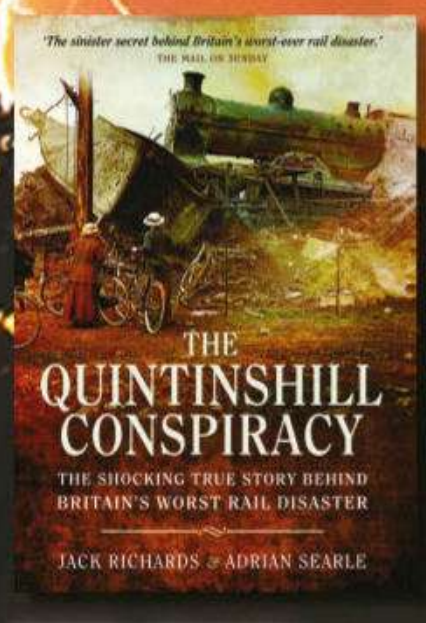

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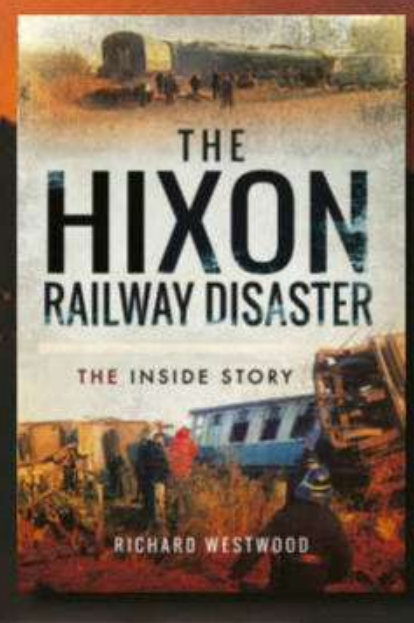

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WELCOME

The magazine that feeds minds!

"Scientists have biohacked insects so they can listen in on conversations"

Top secret spy tech, page 22

If you thought 007 has some cool gadgets to play with, then this issue's special feature is going to be an eye-opener: ever heard of spy insects? Or hacks that can read your texts simply by the way you hold your phone? We've delved into the secret world of private investigation, military intelligence and espionage to bring you some of the most fascinating spy technology on the planet. We've also cast a more scientific eye on the world of paranormal investigations in our ghost hunters feature on page 50. And you can look forward to more augmented reality features too, just follow the instructions on page 4. Enjoy!

Ben Biggs Editor

Meet the team...

James
Production Editor
On page 40, find out how the Berlin Wall cut a city in half and was the dividing line between two ideologies that were locked in conflict.

Scott
Staff Writer
Join the real-life ghostbusters and discover the science behind paranormal investigations on page 50.

Baljeet
Research Editor
Discover how a huge, swirling cloud of dust and gas helped to form the planets in our Solar System, over on page 62.

Jon
Art Editor
With those huge wheels, powerful engine and rugged qualities, what's not to love about tractors? Find out more on page 76.

Ailsa
Staff Writer
See some of the world's impressive rock formations and discover how nature sculpted these unique structures, on page 68.

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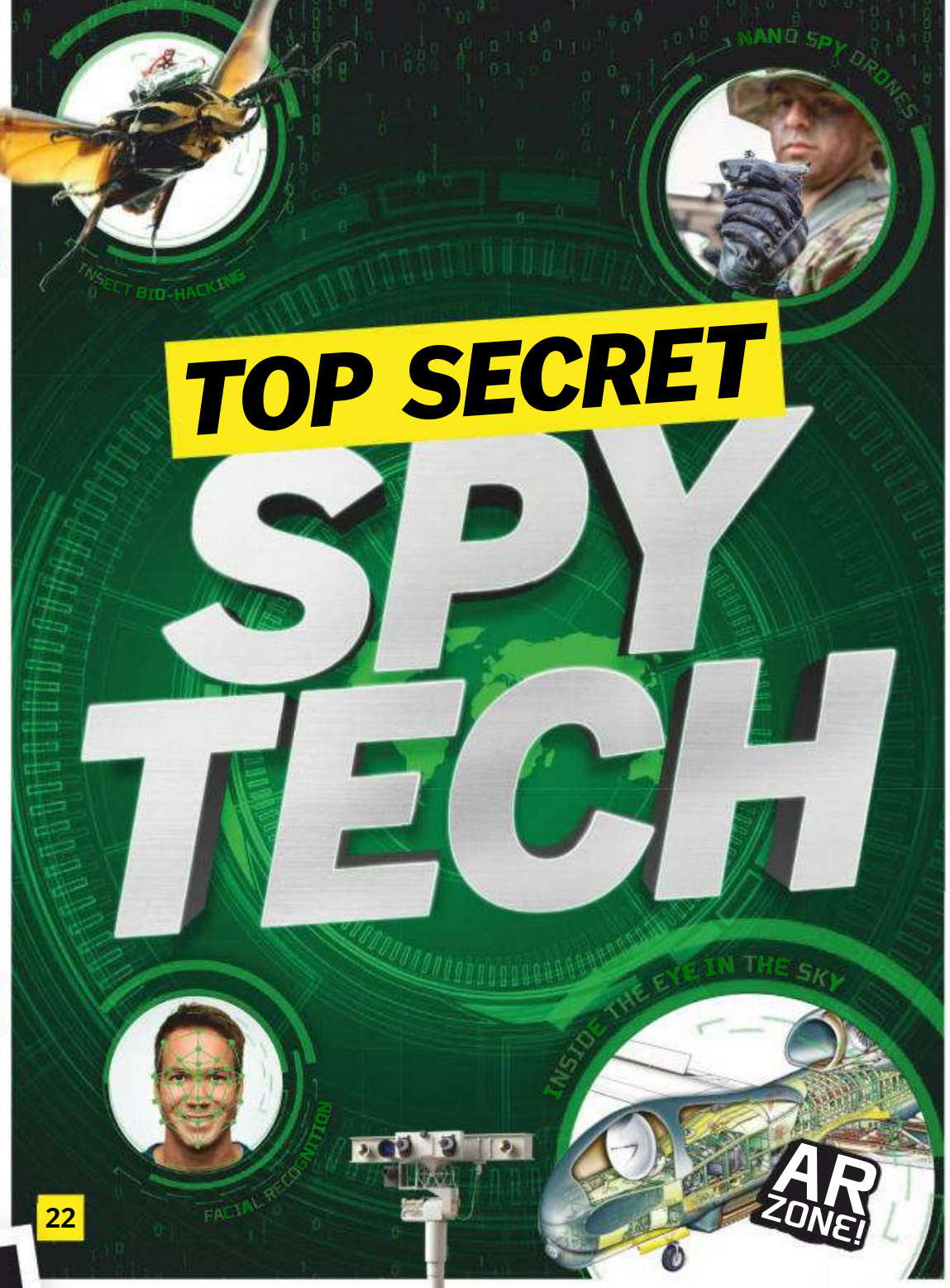

AR ZONE!

NEW

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MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Writer and editor Jo is particularly interested in the natural world and learning about the latest in technological innovations.

Jodie Tyley
The former editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

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REGULARS

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

Steve Wright
Steve has worked as an editor on many publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Jack Parsons
A self-confessed technophile, Jack has a keen interest in consumer gadgets and wearable tech, but also loves to write about projects with much grander ambitions.

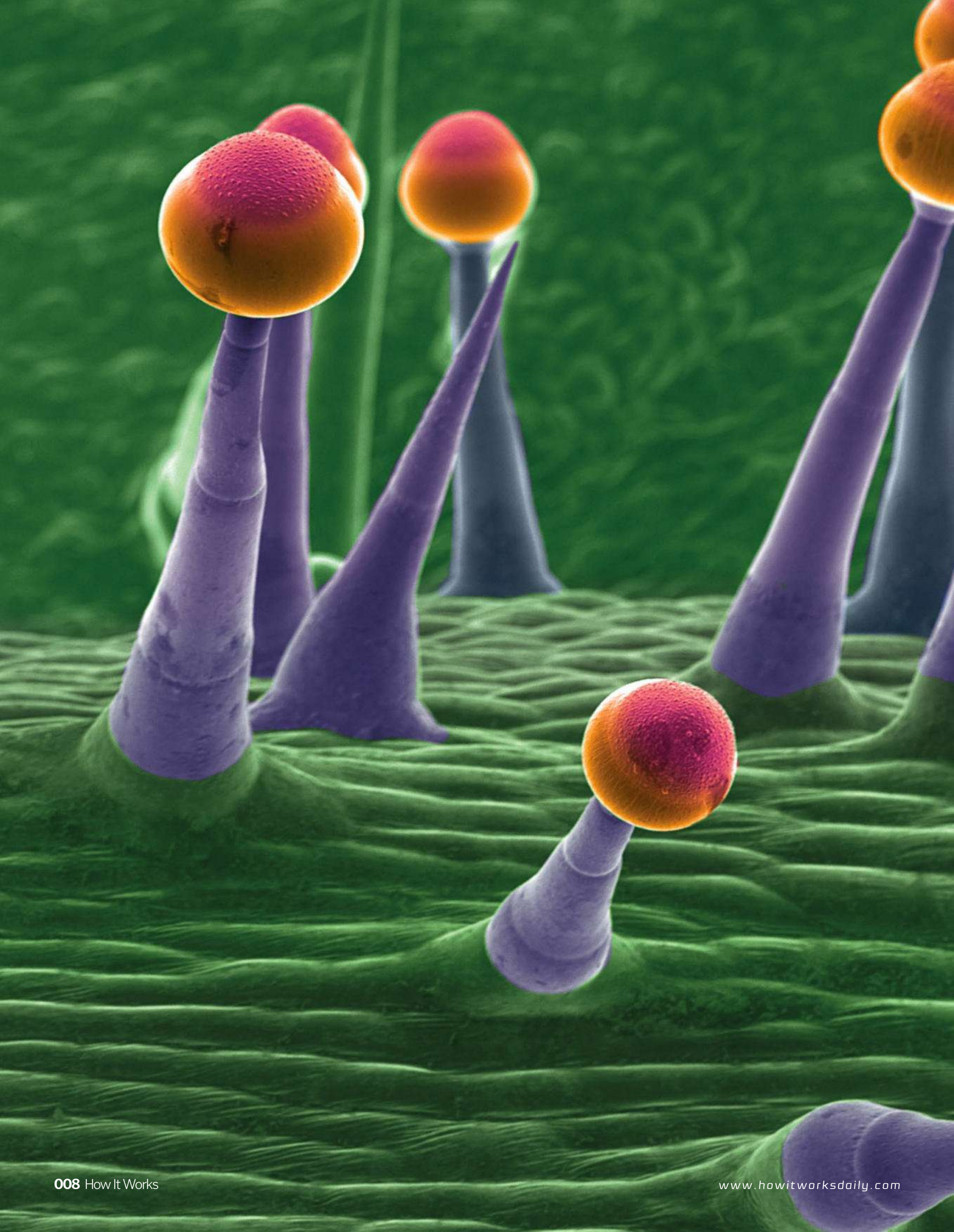
Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law, forensics, crime and deviance. She's also the author of several true crime books.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

Katharine Marsh
Kate has a passion for literature and history, and is currently bringing both together by pursuing an MA in Classical Studies.

Deep in the upside down

Found in tropical and sub-tropical waters around the world, these jellyfish spend most of their time floating and swimming the wrong way up. Known as the upside-down jellyfish, *Cassiopea xamachana* spends its time waving its underparts towards the sky. Living upside-down offers an advantage to this jellyfish because of the symbiotic algae living on its light-bathed limbs. The algae gain energy through photosynthesis, and the jellyfish receives an extra source of nutrition. This image was taken by Mary Anne for The Royal Photographic Society's science photography competition. Discover more about this year's entries at **rps.org/spoty**.



Hidden in a pumpkin patch

Taken using a scanning electron microscope (SEM), this image shows hair-like structures called glandular trichomes on the underside of a pumpkin leaf. Seen here in purple, the stalk part of the cell supports the glandular head, shown in orange. These glandular cells secrete or store secondary metabolites. The pumpkin plant does not use these metabolites for growth or development, but instead uses them for other functions, such as defence, by providing a wax coating.

A witch in space

Found in the constellation Orion, around 1,000 light years from Earth, is a nebula cackling over the cosmos. Known as the Witch Head Nebula, this vast cloud of space dust bears a remarkable resemblance to the hook-nosed witches from a fairytale. Its blue colour is not only the result of a resident blue star, which illuminates the dust cloud, but also the dust grains that scatter light, the same effect particles have in Earth's blue sky.

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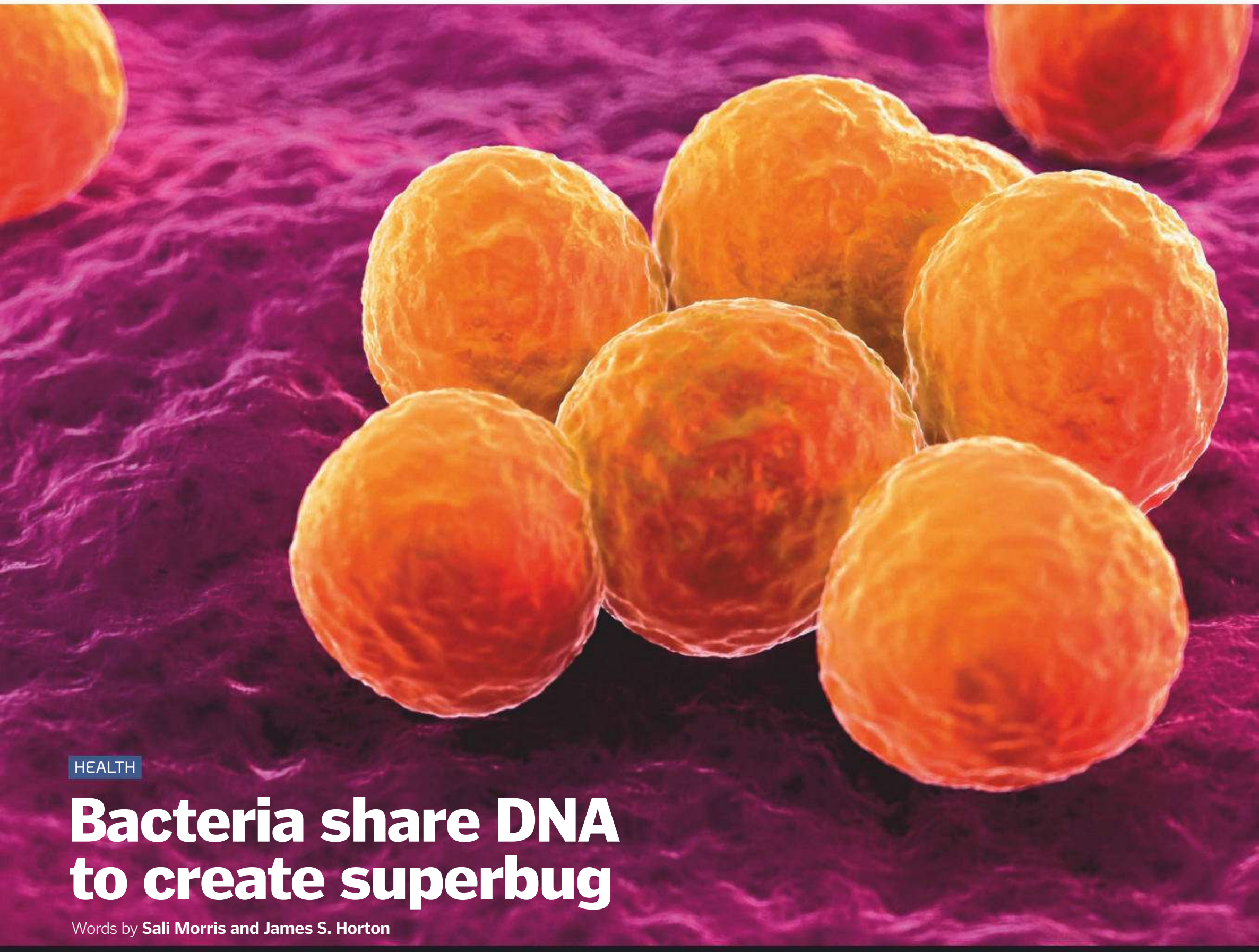


HEALTH

Bacteria share DNA to create superbug

Words by **Sali Morris and James S. Horton**

Antibiotic resistance is spreading fast. When infectious bacteria mutate in a certain way and multiply, they can become resistant to even the most powerful drugs. But research has revealed a worrying alternative way that antibiotic resistance can spread: an organism that passes its resistance to other living bacteria.

In 2012, a 35-year-old man contracted the superbug MRSA (methicillin-resistant *Staphylococcus aureus*) and treated with powerful antibiotics called vancomycin. Although typically effective against MRSA, this superbug strain remained immune. It was later discovered that this MRSA had been gifted a huge chunk of new DNA from a bacteria called *Enterococcus faecalis* to fight against vancomycin.

E. faecalis is a commensal bacterium (one of our 'good bacteria'), which lives in our gut, causing no harm. Our digestive tracts are a hive of microbial activity, hosting single-celled organisms in their trillions. This microbiome is important for maintaining a healthy gut, but also helps to suppress the sinister side of bugs like *E. faecalis*. When patients with weakened immune systems undergo antibiotic treatments, *E. faecalis* can survive thanks to an arsenal of natural resistance mechanisms within its DNA.

When bacteria come together they can exchange information through DNA-encoded instructions. This is known as horizontal gene transfer, where copies of DNA move from one cell to another. Unfortunately, *E. faecalis* and its superbug compatriots have all the best information to share, becoming the ultimate dealers of antibiotic resistance.

This ability to pass this genetic defiance onto MRSA makes understanding *E. faecalis* of paramount importance to scientists. Yet much of the microbe's natural, intrinsic resistance remains shrouded in mystery. *E. faecalis* often has an ace up its sleeve when it is challenged and confronted by antibiotics. If an integral piece of DNA is deleted, for example, it's often found that *E. faecalis* has another section of DNA that can perform the

The bacteria methicillin-resistant *Staphylococcus aureus* (MRSA) can be seen on the surface of a mucus membrane in this 3D illustration

same role, providing it with antibiotic resistance regardless.

However, it's not yet fully understood which pieces of DNA have genetic back-up plans and which do not. A piece of DNA without any back-ups would make for an ideal drug target. And fortunately, we're able to identify these vital pieces in the lab by incrementally deleting segments of DNA.

One by one, each deletion will bring us a step closer to identifying portions of genetic code that are critical for *E. faecalis* to survive. Soon scientists may be able to stack the deck in our favour against this thrifty opportunistic pathogen, and eventually remove the dealer from the game.

www.howitworksdaily.com

ANIMALS

Photo reveals turtle's plastic plight

Words by **Kimberly Hickok**

A photo of a baby loggerhead sea turtle that died after eating 104 pieces of plastic went viral on Facebook earlier this month. The photo was posted by the Gumbo Limbo Nature Center in Boca Raton, Florida, on 1 October and shows the lifeless turtle, no bigger than the palm of your hand, next to the dozens of small pieces of plastic found in the animal's digestive tract, organised in rows.

"We found a piece of a balloon. There was a wrapper that goes on the outside of bottles," Whitney Crowder, the sea turtle rehabilitation coordinator at the Gumbo Limbo Nature Center, told the *South Florida Sun Sentinel*.

This poor hatchling was a 'washback' turtle – a baby that swam a few miles out to sea, where it started eating, but washed back to shore after a few weeks. Washbacks this size are around one to two months old, said Leanne Welch, manager of the Gumbo Limbo Nature Center, which has been rescuing and rehabilitating sea turtles and providing marine science education for more than 30 years.

"It's washback season at Gumbo Limbo and weak, tiny turtles are washing up along the coastline needing our help," Gumbo Limbo Nature Center staff wrote in the Facebook post. "Unfortunately, not every washback survives. 100 per cent of our washbacks that didn't make it had plastic in their intestinal tracts."

"Many of these young turtles are dying from plastic impaction. The plastic plugs them up and causes them to go into septic shock," center staff wrote in response to a comment on the Facebook post. "Plastic pollution is the sad world we live in now. We need to do better."

"Young turtles are dying from plastic impaction. The plastic plugs them up and causes them to go into septic shock"

This baby loggerhead sea turtle couldn't survive the 104 pieces of plastic clogging its digestive tract

The ancient Phoebodus shark may have resembled the modern-day frilled shark

©Getty

ANIMALS

Fossil resurrects 350 million-year-old shark

Words by **Yasemin Saplakoglu**

The ancient seas once churned with strange creatures that have long since vanished, leaving behind only small traces of themselves to anchor our imaginations. But recently, palaeontologists got a rare glimpse of a primordial beast – the first nearly complete skeleton of an ancient shark belonging to the genus Phoebodus. Phoebodus sharks, which grew to about 1.2 metres long, lived over 350 million years ago, long before dinosaurs and the Megalodon came into the planetary story.

Prior to this study, scientists didn't know much about what Phoebodus looked like. However, a recent chance discovery in Morocco has revealed an almost complete fossil of the ancient beast. The fossil was found in the southern region of the Anti-Atlas Mountains, in a 360 to 370-million-year-old layer of sediment that was once a marine basin. Analysis of the fossils showed that the ancient beast had an eel-like body and a long snout, making it resemble the modern frilled shark (*Chlamydoselachus anguineus*), though the two types of sharks aren't related.

Questions about Phoebodus remain and can't be answered with this skeleton alone, as the specimen is missing a perfectly preserved tail fin, which would tell researchers more about how the beast moved.

HISTORY

5,000 year-old 'New York City' uncovered

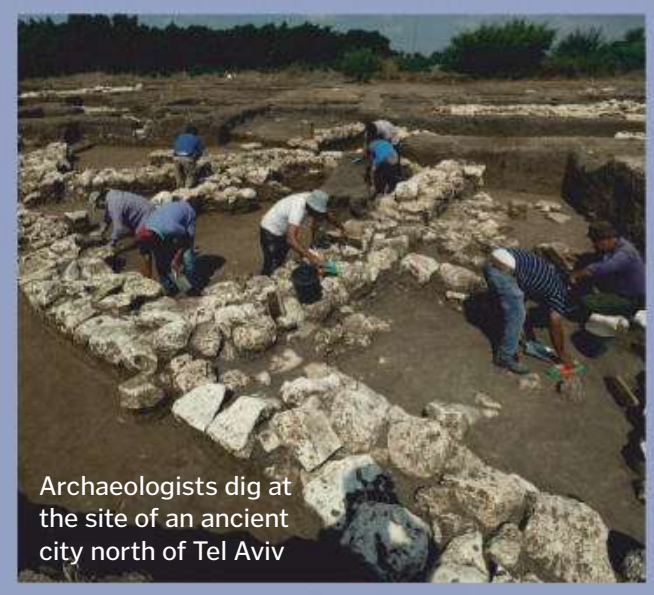
Words by **Yasemin Saplakoglu**

Archaeologists recently discovered an ancient lost city north of Tel Aviv, in Israel. This 5,000-year-old metropolis,bustling with around 6,000 people, was the "early Bronze Age New York," of the region and likely one of the first complex cities in what is now Israel, according to excavation directors at the Israel Antiquities Authority.

The archaeological site, En Esur, located near the valley of Wadi Ara, is around 57 kilometres north of Tel Aviv, and has been undergoing excavations for the past couple of years in preparation for the construction of a new road. During these excavations, archaeologists discovered the ancient city – one of the largest to be uncovered in Israel, which is surrounded by a fortification wall.

The city's intricate design of residential and public areas, streets and alleys points to an organised society and social hierarchy. "This is a huge city – a megalopolis in relation to the Early Bronze Age, where thousands of inhabitants, who made their living from agriculture, lived and traded with different regions and even with different cultures and kingdoms in the area," Itai Elad, Yitzhak Paz and Dina Shalem, directors of the excavation, said. They found evidence of two springs, which might indicate that people earned money from agriculture.

The company that initiated the excavations for the road-building project, Netivei Israel, is now planning to build the road high above the ruins to protect them, according to the statement.



Archaeologists dig at the site of an ancient city north of Tel Aviv

© Forschungstauchzentraum der CAU

PLANET EARTH

Earth's earliest life forms discovered

Words by Mindy Weisberger

Just a billion years after Earth took shape, microbial life was already thriving, scientists say. Analysis of organic traces preserved in ancient Australian rocks – among Earth's oldest – revealed a "perfect snapshot" of microbial life 3.5 billion years ago, the researchers said.

Though individual microbes are too small to be seen with the naked eye, millions of microorganisms can fossilise together to form larger features embedded in rock, known as stromatolites. Many of these structures are preserved in Western Australia's Dresser Formation. Though some geologists aren't convinced that stromatolites represent ancient life, a new study presents "exceptional evidence" of stromatolites' organic origins, researchers recently reported.

Stromatolites have been exposed for billions of years, and weathering has taken a heavy toll on them, erasing chemical information that could link stromatolites to once-living organisms, said lead study author Raphael Baumgartner, who is a research associate with the School of Biological, Earth and Environmental Sciences at the University of New South Wales (UNSW).

What's more, certain geological processes can shape mineral structures that closely resemble those left behind by ancient organisms, and even experts may be hard-pressed to tell them apart, Baumgartner told Live Science. So the scientists dug deep. They drilled dozens of metres below the rocky surface to extract samples that were unaffected by weathering. In those samples, they found filaments of organic material associated with mats of microbes. "This is all backed up by chemical analyses, including organic carbon isotope analysis clearly pointing to biomass," Baumgartner said.

While microbes may have begun to appear billions of years ago, animals took somewhat longer to evolve. The oldest evidence of animal life – preserved chemicals from long-vanished soft bodies – dates to between 635 million and 680 million years ago, and is thought to belong to an ancient relative of modern sponges.

As old as the Australian stromatolites may be, other preserved evidence may represent life that's even older, Baumgartner said. In 2017, another team of researchers identified fossilised microbial evidence in Canada that may be between 3.77 billion and 4.29 billion years old. Study co-author and UNSW professor Martin Van Kranendonk is also investigating stromatolites in Greenland that may be 3.7 billion years old – but whether or not they were produced by living organisms "is highly disputed," according to Baumgartner.

© UNSW Sydney

Stromatolites are sedimentary rocks that were originally formed from layered growth and single-celled photosynthesising microorganisms called cyanobacteria

© Getty

IN ASSOCIATION WITH LIVESCIENCE

A selection of late Bronze Age feeding vessels dated to around 1200 BCE to 800 BCE

© Katharina Rebay-Salisbury

HISTORY

Ancient babies used 'sippy cups'

Words by **Mindy Weisberger**

Babies and young children drank from clay 'sippy cups' during the Bronze Age and the Iron Age, and the practice may have existed as early as 7,000 years ago, a recent study reveals. These spouted artefacts have been found at archaeological sites across Europe, first appearing in the Neolithic period and becoming more common, according to the study.

Scientists suspected that the vessels were meant for feeding babies and toddlers, but some researchers argued that the pottery may have been meant for adults who were sick, injured or elderly. However, researchers have found the residue of animal milk fats, suggesting that the vessels held milk that was likely fed to young children to supplement breastfeeding or to help with weaning.

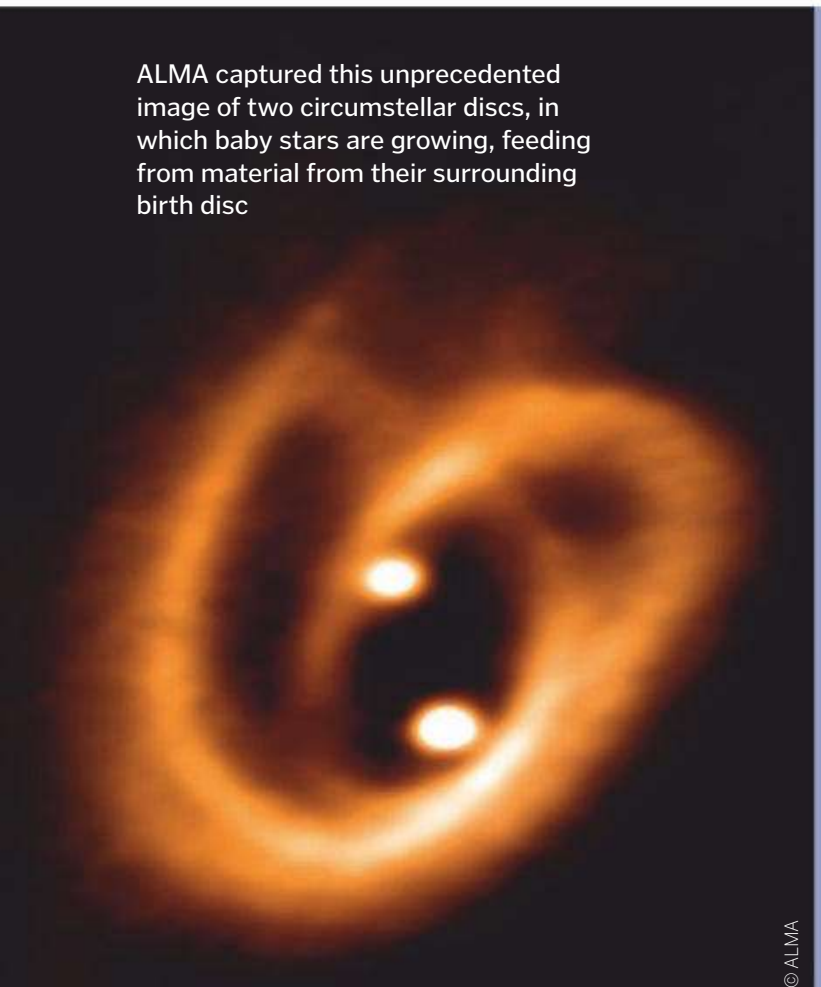
The researchers examined three vessels from the graves of very young children; the eldest was no more than six years old, according to the study. Two of the graves were in a cemetery dating from 800 BCE to 450 BCE, and one grave – a cremation burial – was found in a necropolis dating from 1200 BCE to 800 BCE.

Archaeologists typically look for ancient organic residues by grinding up small pieces of broken pottery – there are often thousands at any given site – and then chemically analysing the powder. However, to keep these vessels intact, scientists carefully swabbed the inside, collecting grains of loose powder. Fatty acids in the residue from the younger vessels hinted that their milk came from ruminants – animals that chew their cud, such as cows, sheep or goats. The older cup held milk that came from nonruminants, perhaps human or pig milk, the study authors reported.

But could a child have comfortably used one of those cups? To find out, the researchers reconstructed one of the vessels, filled it with diluted apple sauce and handed it to an eager one-year-old. "He cupped it in his hands and started suckling from it – and he loved it," Julie Dunne, a senior research associate with the University of Bristol's School of Chemistry, told **Live Science**. "There's something intuitive for a baby about the shape; they all have the same basic shape that you'd hold in between your hands."

© Helena Seidl da Fonseca

If these cups from the Bronze Age and Iron Age were used to feed babies, it's likely that the same is true for similar cups found at other sites that date to the Neolithic, according to the study. These cups offer an intriguing glimpse of an important shift in human history. As people transitioned from hunter-gatherer lifestyles to more agrarian habits, they gained reliable access to milk and cereals to feed their babies, which meant families could grow more quickly, Dunne said.



ALMA captured this unprecedented image of two circumstellar discs, in which baby stars are growing, feeding from material from their surrounding birth disc

© ALMA

SPACE

Stars feed on cosmic mother

Words by **Mindy Weisberger**

Twin baby stars are nestled inside a 'pretzel' of glowing gas and dust in a never-before-seen image captured by the Atacama Large Millimeter/submillimeter Array (ALMA) radio telescope, located in the Atacama Desert. ALMA spotted the twisted display in the Pipe Nebula. Also known as Barnard 59, this immense cloud of interstellar dust lies near the centre of the Milky Way in the constellation Ophiuchus (the Serpent Bearer) about 600 to 700 light years from Earth.

In the centre of the image are two glowing orbs that scientists identified as circumstellar discs – dust and gas rings lit up by a pair of young, growing stars, according to a recent study. Looping around the twin stars is the larger dust ring that birthed them. Filaments connect the stars to the disc; the stars siphon matter through these tendrils, feeding off the disc as they grow.

Each of the dust rings surrounding the two stars is about as large as our Solar System's asteroid belt – roughly 225 million kilometres across. Their mass is comparable to "a few Jupiter masses," the scientists wrote. The quantity of dust contained in the parent disc is much greater; comparable to about 80 Jupiters. "We have finally imaged the complex structure of young binary stars with their feeding filaments connecting them to the disc in which they were born. This provides important constraints for current models of star formation," Paola Caselli, head of the MPE Center for Astrochemical Studies, said.

ANIMALS

Scientists implant false memories into birds

Words by **Stephanie Pappas**

Zebra finches usually learn to sing from their fathers. But now, scientists have taught the birds to memorise a tune without ever learning it – by implanting memories of the songs in the birds' brains.

This strange experiment was designed to discover the brain pathways that encode note duration in the birds. Ultimately, the point is to draw parallels with how humans learn to speak. Hopefully, the research will help scientists target genes and neurons to improve language learning in people with autism and other conditions that affect vocalisation.

Zebra finches (*Taeniopygia guttata*) are small, social birds native to Central America and popular as pets. Just as infant humans learn language by imitating what they hear, zebra finches listen to their fathers sing and then practise the tunes. The new research reveals how the animals pull it off. Todd Roberts, a neuroscientist at the University of Texas Southwestern O'Donnell Brain Institute, and his colleagues used optogenetics to modify the finch's neurons without ever exposing them to singing. This technique involves using light to

"The researchers were able to encode memories"

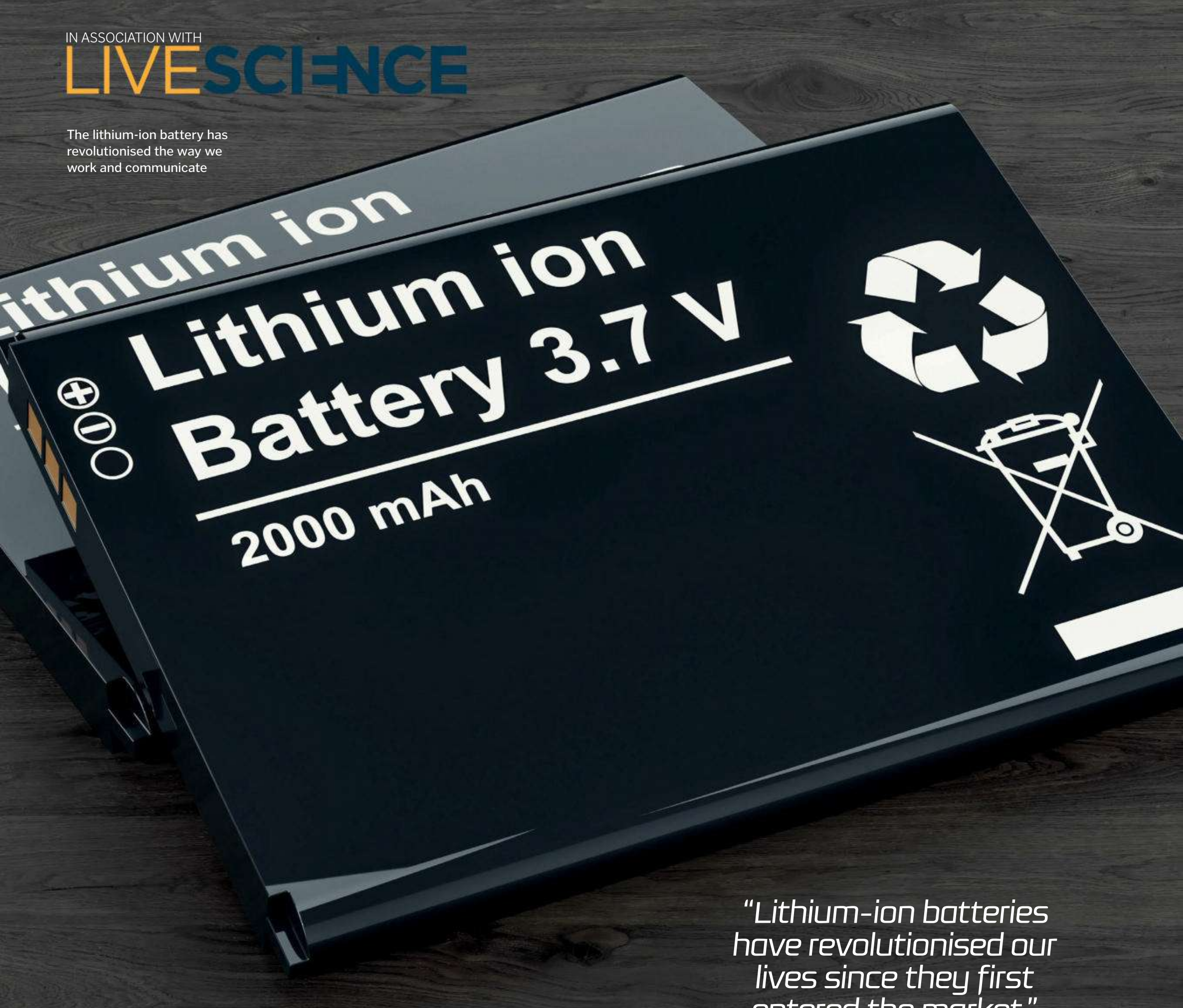
control the behaviour of photosensitive proteins in neurons, or brain cells, essentially allowing researchers to control when a neuron fires. Using this tool, the researchers were able to alter brain activity in a sensorimotor area known as Nif, which sends information to a specialised songbird brain region called the HVC. This area is involved in learning and reproducing bird songs.

By pulsing light in a rhythm, the researchers were able to encode 'memories' in the finches' brains, such that the birds' notes would match the duration of the light pulses. It was as if a father was making these instructions for the bird to memorise, but no father finch was present.

Note duration alone isn't enough to teach a finch a full song; the birds must learn other aspects of the melody, such as pitch. "We're not teaching the bird everything it needs to know – just the duration of syllables in its song," Roberts said. "The two brain regions we tested in this study represent just one piece of the puzzle." With more pieces found, he added, it might be possible to teach the birds to sing a full melody without any teacher at all. "But," Roberts said, "we're a long way from doing that."

Scientists have taken over the role of father to teach zebra finches their songs

The lithium-ion battery has revolutionised the way we work and communicate



"Lithium-ion batteries have revolutionised our lives since they first entered the market"

TECH

Lithium-ion battery inventors win Nobel Prize

Words by Jeanna Bryner

It's both the bane of our existence and a godsend. The rechargeable lithium-ion battery powers most of our devices, from smartphones to laptops to electric cars. And the three men who were integral to its development have just been awarded the Nobel Prize in chemistry. John B. Goodenough, M. Stanley Whittingham and Akira Yoshino will share this year's Nobel "for the development of lithium-ion batteries," the Royal Swedish Academy of Sciences announced.

Whittingham, of Binghamton University, State University of New York, while developing technologies for fossil fuel-free energy, discovered an energy-rich material that he used to create a cathode (negatively charged electrode) in a lithium-ion battery. The resulting battery, with metallic lithium as the anode, created two volts of power. Goodenough, of The University of Texas at Austin, created a similar battery using cobalt oxide (also with little lithium ions hidden in its empty spaces) as the cathode, resulting in as much as four volts of power.

Then, building on Goodenough's cathode, Yoshino "created the first commercially viable lithium-ion battery in 1985," the Nobel Prize foundation said. Yoshino, who is at the Asahi Kasei Corporation, Tokyo, and Meijo University, Nagoya, Japan, switched out the material for the anode. Instead of metallic lithium, he used a carbon material called petroleum coke that can hide lithium ions in its molecular spaces.

"Lithium-ion batteries have revolutionised our lives since they first entered the market in 1991. They have laid the foundation of a wireless, fossil fuel-free society, and are of the greatest benefit to humankind," the Nobel Prize foundation said.

The Fermi Bubbles tower over the Milky Way and suggest a gargantuan cosmic explosion from the centre of our galaxy

© NASA

SPACE

Cavemen witnessed a galactic explosion

Words by **Brandon Specktor**

At the centre of our galaxy is a supermassive black hole that, apparently, likes to blow bubbles. Ballooning out of both poles of the galactic centre, two gargantuan orbs of gas stretch into space for 25,000 light years apiece (roughly the same as the distance between Earth and the centre of the Milky Way), though it's visible only in ultra-powerful x-ray and gamma-ray light. Scientists call these cosmic gas orbs the Fermi Bubbles and know that they're a few million years old.

What caused this bout of galactic indigestion, however, is one of our galaxy's biggest mysteries. Now, by looking for evidence of this violent bubble-blowing event in the scorched clouds of gas in one of the Milky Way's satellite galaxies, researchers have reconstructed a plausible explanation for the bubbles' birth.

According to a recent study, the Fermi Bubbles were created by an epic flare of hot, nuclear energy that shot out of the galaxy's poles roughly 3.5 million years ago, beaming into space for hundreds of thousands of light years. The effect would have been "like a lighthouse beam" that shone out of our galaxy's middle for 300,000 years, lead study author Joss Bland-Hawthorn, director of the Sydney Institute for Astronomy at the University of Sydney, told **Live Science**. And, given the recent (cosmically speaking) date of the explosion that Bland-Hawthorn and his team calculated, the blast may even have been visible to early humans. "It's an amazing thought that, when cave people walked the Earth, if they'd looked off in the direction of the galactic centre, they'd have seen some kind of giant ball of heated gas," Bland-Hawthorn said.

Using mathematical models, Bland-Hawthorn and his colleagues showed how such an explosion of energy – known as a Seyfert flare, a type of outburst that may occur in galaxies with active black holes every 10 million years or so – could blast out of the galactic centre and reach all the way to the hottest regions of the Magellanic Stream. They calculated that, in order to reach those affected parts of the stream, the explosion must have occurred between 2.5 and 4.5 million years ago – a time when humankind's early ancestors were already walking the Earth.

While those primitive human ancestors may have seen the mysterious flare overhead, it's unlikely that they were impacted by its energy, thanks to Earth's protective atmosphere, Bland-Hawthorn said. That's good news for us, he added; Seyfert flares occur somewhat randomly in galaxies like ours, and previous research suggests that there may be others on the way.

WISH LIST

The latest HOME tech

Bodyclock Luxe 750DAB

Price: **£199 (approx $250)**
lumie.com

Getting up on Monday morning is something most of us don't take pleasure in doing. However, the Bodyclock Luxe 750DAB alarm clock aims to make you rise from your cosy sheets more comfortably. Replicating a sunrise and sunset, the Bodyclock mimics the gradual increase or decrease of light in your bedroom at a speed you determine. This alarm clock also boasts over 20 wake and sleep sounds, such as bird songs and waterfalls.

© Lumie

Knocki

Price: **$99 (approx £80)**
knocki.com

We often refer to our homes as 'smart homes' due to the amount of interconnected smart devices we have. However, this portable device turns your physical home into an interactive control. Knocki responds to simple taps on a surface to carry out a function. For example, three taps on a wall could start your TV, or two on your nightstand could snooze your alarm. This device is fully customisable, and with WiFi connection the Knocki can pair with devices all around your home.

© Knocki

© Awair

Awair 2nd Edition

Price: **£179 / $199**
getawair.co.uk

The quality of the air in our homes can have a direct effect on our health, and keeping track of dust and pollution can help us to control issues such as allergies. Awair is a small device that can analyse the air in your home and give you information about five key aspects; dust, temperature, humidity, chemical pollution and carbon dioxide levels. Using an array of built-in sensors, Awair can offer real-time suggestions on how to best improve your environment and give your home an overall air-quality score. Partnered with home devices like the Nest thermostat, Awair can communicate with other devices to change home conditions. For example, in an instance of increased carbon dioxide levels, Awair can inform Nest when to turn on your fan to tackle the build-up.

Monoprice MP Voxel 3D printer

■ Price: **£329.28 ($399)**
monoprice.uk (monoprice.com)

Bring your digital designs to life with this fully enclosed, high-tech 3D printer. 3D printing has revolutionised the way we manufacture and design commercial goods, but the MP Voxel brings the power of 3D printing to our homes. Lightweight and with a touchscreen, the MP Voxel features 8GB of internal memory for storing digital 3D models, has a USB port and a WiFi-enabled camera, so you can watch and record your prints taking shape.

© Monoprice

Brilliant

© Brilliant

■ Price: **From $299 (approx £240)**
brilliant.tech

Take complete control of your home with this brilliant smart switch. Sitting in place of a conventional light switch, Brilliant is an all-in-one smart device that can give you a single control for your smart doorbell, music, lights, etc. With the built-in microphone and camera, Brilliant can transform into a room-to-room intercom at the touch of a button or using voice activation, thanks to an integrated Amazon Alexa.

August Smart Lock Pro

■ Price: **$279 (approx £225)**
august.com

Using the August app, this smart lock enables you to control and monitor who is coming in and out of your home. Grant access to your home at the touch of a button or at the sound of your voice remotely from wherever you are. The August Smart Lock Pro will also alert you to the status of your home's security, and with the auto-lock feature it will automatically unlock the door as you approach and lock when you leave.

© August Home

APPS & GAMES

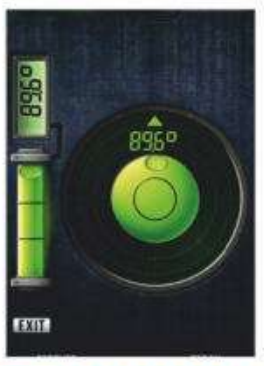
magicplan

■ Developer: **Sensopia Inc**
■ Price: **Free / Google Play / App Store**

If you are looking to renovate or redesign your home, then magicplan is a great tool to use. Create 2D and 3D floor plans and design your ideal home from scratch.

Precise Level

■ Developer: **JonyUps / Robert Sniezynski**
■ Price: **Free / Google Play / App Store**



If you haven't got a spirit level to hand and your brickwork badly need measuring, then this handy spirit level smartphone app can keep you on the DIY straight and narrow.

Dulux Visualizer

■ Developer: **AkzoNobel**
■ Price: **Free / Google Play / App Store**

With the Dulux Visualizer, you can scan an object and get the name of the corresponding paint colour, then virtually apply that shade to your walls and see if it's a colour you want.

IKEA Place

■ Developer: **Inter IKEA Systems B.V.**
■ Price: **Free / Google Play / App Store**

Ikea has made interior design even easier with this augmented reality app. Simply select an item from their catalogue and digitally place it in your room to see how it looks.

TOP SECRET SPY TECH

EXPLORE AN INCREDIBLE WORLD OF ALL-SEEING SPY DRONES, BIOHACKED INSECTS, TRACKING CANNONS, AND MORE

Words by **Jack Parsons**

There are only three words that come to mind when you think of spy gadgets: 'Bond, James Bond'. For almost 50 years, the fictional MI6 agent has wowed cinemagoers fighting evil villains with an arsenal of new-fangled gizmos – all for queen and country.

When 007 debuted in 1962's *Dr No*, real-life spies were caught up in the Cold War. From 1946 to 1991, the United States and the Soviet Union were arch-rivals. Although they never fought directly, both powers were constantly prepared for nuclear war. To gain the upper hand, they felt they needed to know what the other was up to and what their military was capable of. Secret agents working for the CIA and KGB would intercept messages, crack codes and infiltrate numerous organisations to uncover each other's state secrets. From hi-tech surveillance to secret weapons, some of the gadgets these spies carried could even give the fictional Q Branch a run for its money.

> "A German firm even makes *Skyfall*-style pistols that are coded to a particular user"

Today, some of the Bond films' most extraordinary inventions are everyday essentials, or even feel a bit old hat – the car phone in *From Russia With Love*, *Diamonds Are Forever*'s fingerprint scanner, a watch that can receive messages and calls from *For Your Eyes Only*. No doubt Tesla owners think of Pierce Brosnan's remotely controlled BMW every time they summon their car with a tap on an app. Dubai firefighters now use *Thunderball*-style jetpacks. A German firm even makes *Skyfall*-style pistols that are coded to a particular user. We're still waiting for an alligator-shaped personal submarine, though.

If you and I can carry pocket-sized computers with built-in cameras and access to satellite navigation, it's no surprise that today's spies have upgraded their gadgets, too. Adapting to the digital age, spycraft is now state of the art, embracing AI, quantum physics and more.

FACIAL RECOGNITION SOFTWARE

Super-smart CCTV

Facial recognition software already exists. It's how you can unlock your smartphone just by looking at it. Authorities have used it to analyse CCTV images and identify people for years. More recently, police forces have been trialling 'live facial recognition', which scans footage of crowds in real time. While this has prompted a backlash from privacy campaigners, it's just the tip of what the technology can do.

Algorithms are getting better at identifying faces all the time. It's at the point where security company Digital Barriers' software can detect people even with covered faces, such as those with a scarf wrapped around it. Meanwhile, Amazon's Rekognition tech – which is already used by the FBI and other US agencies – not only identifies people but can tell if they're happy, sad or fearful. Better described as 'computer vision', Rekognition can spot specific activities – including 'getting out of a car' and 'delivering a package' – and read written words.

1 Capturing your image

A picture of your face is captured from a photo or a video. It doesn't matter if you're in a group shot or if you are not looking directly at the camera – the technology can still be used on your image.

2 Scanning your features

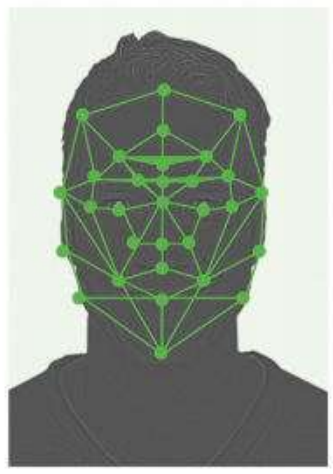
The software maps the geometry of your face, measuring the distance between your eyes, forehead and chin. Known as your 'faceprint', this formula is unique to each person.

3 Searching the database

Your faceprint is automatically compared to a database of known faces. The UK police can search through about 20 million facial images. The FBI can search through 412 million.

4 Making a match

The software decides if your image matches anything in its records. But the technology is far from foolproof; a Scotland Yard report found the UK police's system was still 81 per cent inaccurate.



PHONE HACKS

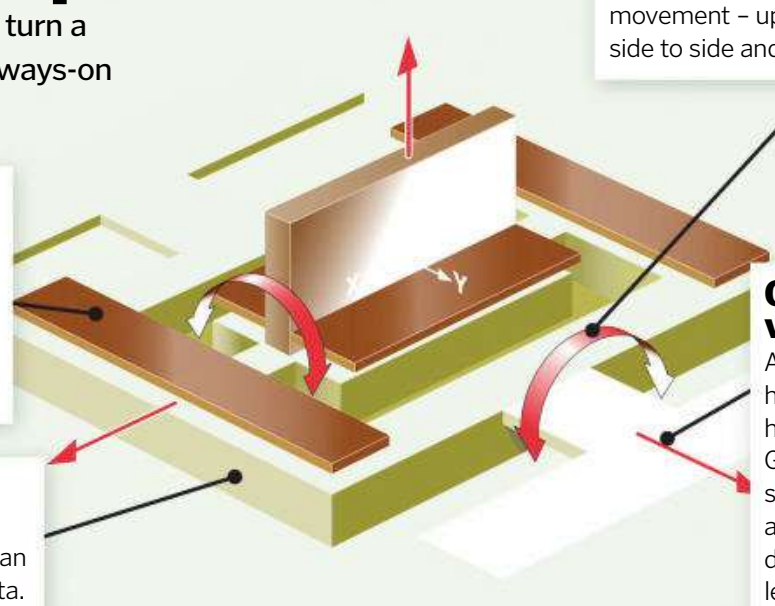
Listening to phone vibrations

You might already think twice about letting an app access your smartphone's microphone, GPS or camera. But what about your gyroscope? Whenever you play a racing game where you tilt the screen to steer, this motion sensor detects what you're doing. But researchers from Stanford University and Israeli defence research group Rafael found that it can even detect soundwaves.

They created software called the Gyrophone that turned the sensor into a microphone. It was able to accurately identify numbers spoken aloud 65 per cent of the time. And the software could also use the gyroscope to distinguish between different speakers, even recognising their gender. The researchers were confident that algorithms could soon learn to recognise more words.

Jerry-rigging the gyroscope

How the Gyrophone can turn a motion sensor into an always-on listening device



Coriolis force

The gyroscope contains two tiny elements that are always vibrating. When you move your phone, the movement is measured by how it affects these elements.

No way to stop it

Neither Apple nor Android phones enable users to block an app's access to gyroscope data.

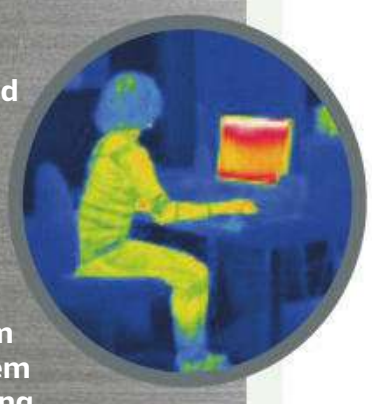
Angular movement

Your phone's gyroscope measures three kinds of movement – up and down, side to side and circular rolling.

Good vibrations

As audible sound is higher than 20 hertz, the Gyrophone software ignores any vibrations it detects that are less than this.

Harvesting passwords from heat maps



Spies might not even need to hack a computer to gain entry to its files. They could guess the password just by snapping a thermal image of the keyboard.

Keys remain warm from your fingers touching them after you've finished typing. Scientists from the University of California, Irvine (UCI) used an infrared camera to detect this heat residue. During their experiments, even ordinary people could use these images to work out complex passwords. Secret agents might also be able to use this 'Thermanator' approach to glean PIN codes or other sensitive information.

Spies would need to take a picture within a minute of the target using a keyboard, or the heat would fade away. But they could cause a distraction to lure away the user at the right time. The UCI scientists suggested placing a camera in advance. Previous researchers have also used thermal imaging to work out touchscreen passwords and crack safes with combination locks.

SPY DRONES The USA's eye in the sky

The RQ-4A Global Hawk goes above and beyond normal mass surveillance. This robotic spy plane can track a person on the ground from a height of almost 18,000 metres – even if it's cloudy. And it can travel half way around the world on a single tank of fuel.

Though it doesn't have any weapons, the spy drone was made by Northrop Grumman for the US military. It became famous for gathering intelligence in war zones like Iraq and Afghanistan. It also patrols the Pacific and skirts coastlines, where its powerful sensors can see much further than the international water line.

This spy drone can provide detailed information to the military almost instantly

AR ZONE! SCAN HERE

Global Hawk

A look inside the US military's mighty spy drone

Heavy load
While unarmed, a Global Hawk can carry an extra 1,360kg of specialist spy kit and communications equipment.

Onboard computer
Though a pilot remotely guides it through takeoff and can take control at any time, the drone can fly itself.

Around-the-clock surveillance
A high-resolution camera can pinpoint locations by day, while electro-optical and infrared imaging are used for night-time missions.

Constant communication
A data link to military satellites and line-of-sight communications to ground bases mean the drone can relay images almost instantly.

All-weather radar
The Global Hawk can provide long-range scans with a much more detailed picture than conventional radar, even in bad weather.

The hypersonic SR-72 will be able to fly from London to New York in less than an hour

Flying into the future

The Global Hawk may be a high flyer, but new spy drones are hovering on the horizon. The Black Hornet Nano is already being used by NATO forces. The size of a sparrow and weighing just 33 grams, soldiers can carry it in their pocket. To see what's coming or check for hidden bombs, this mini helicopter can scout ahead up to two kilometres, providing full-colour footage or thermal imaging.

The Airbus Zephyr holds the world record for the longest unmanned flight, lasting over 25 days – running on solar power. Developed in the UK, it can carry up to five kilograms of sensors and communication equipment, with a larger version in the works. Solar drones might replace spy satellites, as they're cheaper to launch and faster to move into position over a target.

But for real speed, you'll want the Lockheed SR-72. Though it won't arrive until 2030, this drone is being fitted with advanced jet engines that can reach around 7,200kph. Travelling at six times the speed of sound, it would be able to photograph vast areas in no time at all while outrunning existing surface-to-air missiles. It might also be fitted with weapons to strike targets.

The solar-powered Airbus can takeoff like a regular plane before cruising the stratosphere

The Black Hornet Nano's size makes it hard to spot or hear it approaching

Rolls-Royce engine
The Global Hawk is powered by a powerful Rolls-Royce AE 3007 turbofan engine.

Flying high
The drone can fly as high as 18km – the same altitude as Concorde – making it harder to shoot down.

Heated fuel system
Integrated heaters help keep the fuel flowing at super-chilly high altitudes, without the need for expensive specialised fuels.

Going the distance
The aircraft can fly for over 32 hours at a time, covering up to 22,780km.

Giant drone
With a length of 14.5m and a wingspan of 39.9m, the aircraft is about the size of an American U-2 spyplane or a small private jet.

"It can travel half way around the world on a single tank of fuel"

BUGS & WIRES

The unhackable phone

The Blackphone 2 offers its own encrypted audio call system, so no one can eavesdrop on conversations

Talk in private
The Blackphone 2 has its own encrypted audio call system to prevent people from listening in.

Smart networking
The device stops you from joining insecure Wi-Fi networks that could provide a backdoor for bugs and hackers.

Protects your needs
The phone's preloaded with security apps straight out of the box, but your settings can be customised in the Security Center app.

Responds to threats fast
The Blackphone 2's creator, Silent Circle, is committed to fixing bugs and issuing security updates within 72 hours of discovery.

Enhanced OS
The device runs on its own operating system, Silent OS, which is an enhanced version of Android.

"If it's lost or stolen, you can either remotely turn the phone off or wipe everything that is on it"

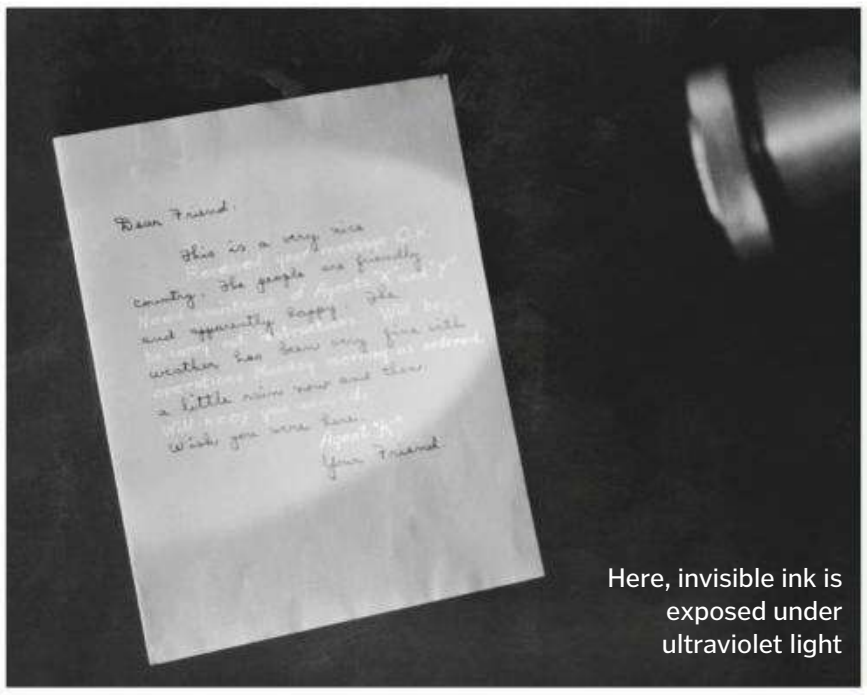
Secure to the core
The device's memory is encrypted from the moment you turn it on, making it impossible to decode its content without the correct PIN.

Burner phone
If it's lost or stolen, you can either remotely turn the phone off or wipe everything that is on it.

DNA-capturing spy pen

The Uzi Tactical Pen is fitted with a razor-sharp crown on top of its lid. When jabbed into an attacker, it not only causes extreme pain but also captures a DNA sample, so you can identify them later. The crown also doubles as a glass-breaker, while the pen even writes underwater.

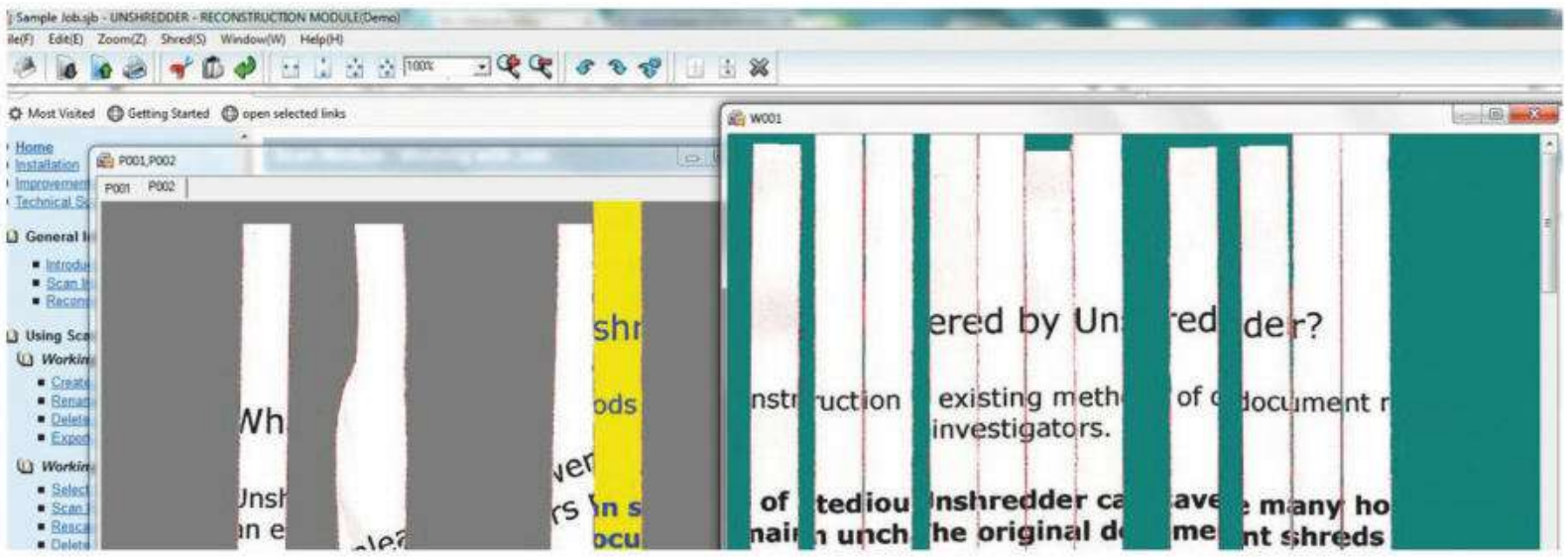
A literal example that the pen is mightier than the sword, the Uzi Pen can even break glass



Here, invisible ink is exposed under ultraviolet light

Don't overlook invisible ink

Though it might sound old-fashioned, invisible ink is still used in some cases. Members of a Russian spy ring who were caught in the United States in 2010 admitted to using it to write and pass along secret messages. An al-Qaeda operative was also caught smuggling invisible information into the UK in 2008. One reliable method to create invisible ink is to scribble a note in lemon juice, which can then be revealed by heating the paper.



Document unshredder

If you think turning classified documents into confetti is going to make them disappear, think again. Unshredder is a computer program that can reassemble destroyed documents as though they were a puzzle. It analyses each shred's characters – including size, colour and font – to find matching pieces. The innovative software is used by police departments, government agencies and even private investigators.

5 FACTS ABOUT HOW TO TELL IF YOU'VE BEEN BUGGED

1 Listen out for buzzing
While listening devices are designed to be discreet, they can still give off a quiet buzz. If your phone calls crackle, this might be a bug interfering with your signal.

2 Investigate smoke detectors
Smoke detectors are a great place to hide spy kit as they're often in the centre of a room and have a built-in power supply. Also, check your speakers and lamps.

3 Check for two-way mirrors
If you suspect a mirror is not all that it seems, turn off all the lights and shine a torch against the glass. If it's a two-way mirror, you'll see the room on the other side.

4 Look for infrared lights
Most smartphone cameras can actually detect infrared. Scan your camera around the room and see if any unexpected light sources appear on the display, which might point to a hidden camera.

5 Scan for signals
Most modern bugs have their own data connection but may also give off Wi-Fi signals. Use a phone or laptop to look for nearby networks that you don't recognise.

GPS cannon catches getaway drivers

StarChase takes the pressure out of high-speed pursuits. It offers a cannon (see inset image on the right) that fires laser-guided GPS beacons that stick to fleeing vehicles. Police officers can then track the criminal's location from their phone, so they don't have to worry about criminals getting away. As if a handheld launcher wasn't cool enough, StarChase has also fitted its GPS cannon to the grill of some US police cars.

StarChase makes tracking fleeing criminals far easier for police – they can run, but they can't hide

BELIEVE IT OR NOT

Bugged by biohacked beetles

Scientists have biohacked insects so they can listen in on conversations. 7.5cm-long flower beetles were fitted with tiny radio receivers on their backs, plus electrodes on their legs and flight muscles. This was so researchers at Nanyang Technological University in Singapore could not only hear what was going on but also pilot the creatures like drones. They could make each walk, fly left or right or hover by remotely stimulating the electrodes. The experts say the cyborg beetles could be used to covertly spy on terrorists or help hunt for people buried under rubble after a disaster.

Now something as small and innocent as a beetle can be used to spy on people

A computer virus spread by sound

To keep secrets safe on a computer, IT experts isolate it. The device never connects to the internet or any network. Known as creating an 'airgap', this is not foolproof. In 2010, the Iranian nuclear program was crippled by the Stuxnet virus when an infected USB stick was plugged in. But this still required a physical device to be connected. Leading cybersecurity expert Dragos Ruiu no longer thinks this is the case. He claims to have discovered malware he calls 'BadBIOS' that spreads using ultra-high speaker frequencies that are detected by a machine's microphone.

Tinker, tailor, soldier... stone

At the start of the millennium, the UK ran a spy ring in Russia revolving around a rock. Hidden in plain sight on a Moscow street, it contained a transmitter. A Russian mole is said to have used a handheld computer to beam digital data to the device while walking by. A British agent would then stroll by and wirelessly download the stone's secrets. Russia's spy agency, the FSB, discovered the plot and exposed it in 2006. Prime Minister Tony Blair denied it at the time, but his chief of staff later admitted that the 'spy rock' was real.

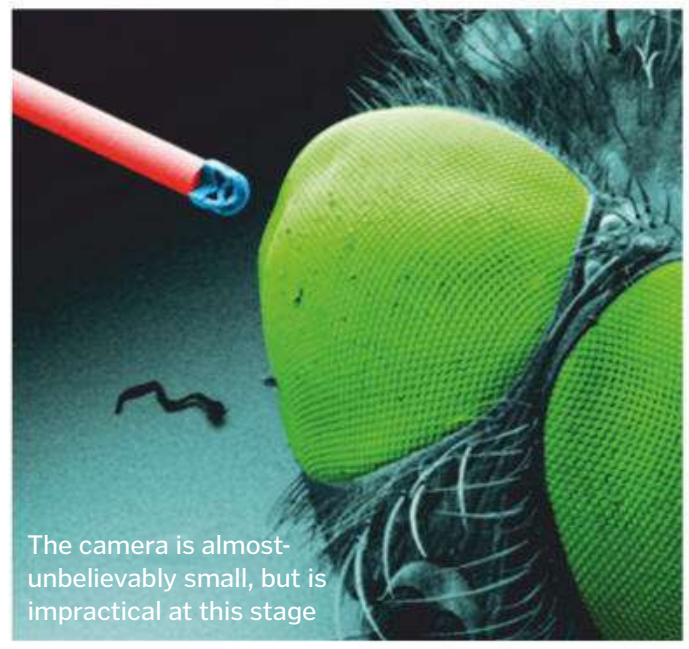
© Getty

Keeping tabby on the Soviets

It's not just today's secret agents pushing science to the limits. During the 1960s, the CIA tried to use a cat to spy on the Soviet Union's embassy in Washington DC. Codenamed Acoustic Kitty, they surgically implanted a microphone into the animal's ear canal, a radio transmitter in the base of its skull and an antenna along its tail. That was the easy bit. They also had to train the cat to follow instructions and ignore its desire to wander off and look for food. Unfortunately, Acoustic Kitty didn't survive its first mission. When the agents released the cat opposite the Soviet compound, it was hit by a taxi while crossing the road.

Speck of dust spy camera

Researchers at the University of Stuttgart used 3D printing to create a camera with three lenses that's just 100 micrometres wide. For scale, one micrometre is 1,000 times smaller than a millimetre. Images can be transferred using an optical fibre the size of two human hairs. While the camera would be almost impossible to detect, it may be some time before spies use it on missions. Currently, it can only focus on objects that are 3mm away.



The camera is almost-unbelievably small, but is impractical at this stage

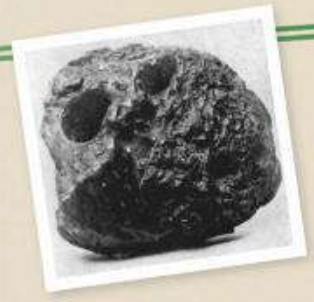
SPY GADGETS THROUGH TIME

400 BCE
Writing on leather wrapped around a baton called a scytale, Spartan generals trade encrypted messages that can only be read using a rod of the same size.

1466
Italian architect and painter Leon Battista Alberti invents one of the first ciphers to use more than one alphabet.

1777
During the American War of Independence, British spies hide messages in hollow silver bullets, which can be swallowed if captured.

1917
During World War I, both sides use homing pigeons fitted with cameras to take reconnaissance photos of enemy installations.



1864
The Confederate secret service sinks Union steamships with 'coal torpedoes' that explode when shovelled into the furnace with the rest of the fuel.

1778
George Washington's allies use 'sympathetic stain' invisible ink to disguise letters that are sent back and forth across the Atlantic.

1923
Resembling a typewriter, the Enigma machine uses a series of rotors to scramble German radio communications.

1939
This ordinary-looking pipe issued to British special forces fires a small projectile that can kill at close range.

1960s
Spies snap documents with this special camera, which reproduces them less than a millimetre in diameter for easy smuggling.

1940s
British agents smuggle fake Monopoly board games into POW camps, which contain maps and compasses disguised as playing pieces to help captives escape.

1942
This glove gun issued to US Navy intelligence officers keeps both hands free, and fires when you punch an attacker.

1960s
The Romanian Securitate listens in on Western diplomats' top-secret conversations by hiding a microphone in the heel of their shoes.

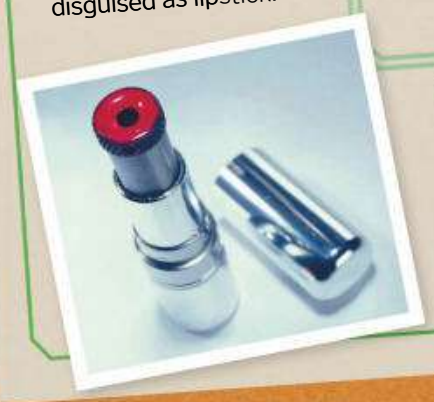
1949
West German spies carefully aim this Steinbeck ABC wristwatch camera while pretending to check the time.

1957
KGB agent Bohdan Stashynsky kills Ukrainian dissidents with a double-barrelled gun that sprays cyanide gas.

1965
Nicknamed the 'Kiss of Death', female KGB agents can blow away enemies with a pistol disguised as lipstick.

1978
Georgi Markov, a Bulgarian journalist, is shot with a poison dart fired from an umbrella while waiting for a bus in London.

2008
Codenamed Nightstand, the NSA develops a gadget that can wirelessly hack Windows computers and deliver cyberattacks from up to 13km away.



1970s
The CIA develops glasses tipped with a cyanide pellet that US captives can chew through if they are tortured – killing themselves but protecting their secrets.

1980
With bugs so easy to hide, spies use electronic countermeasure kits to detect nearby transmitters before discussing state secrets.

2009
Resembling a normal USB cable, this device enables NSA agents to remotely install surveillance software when plugged into a computer.

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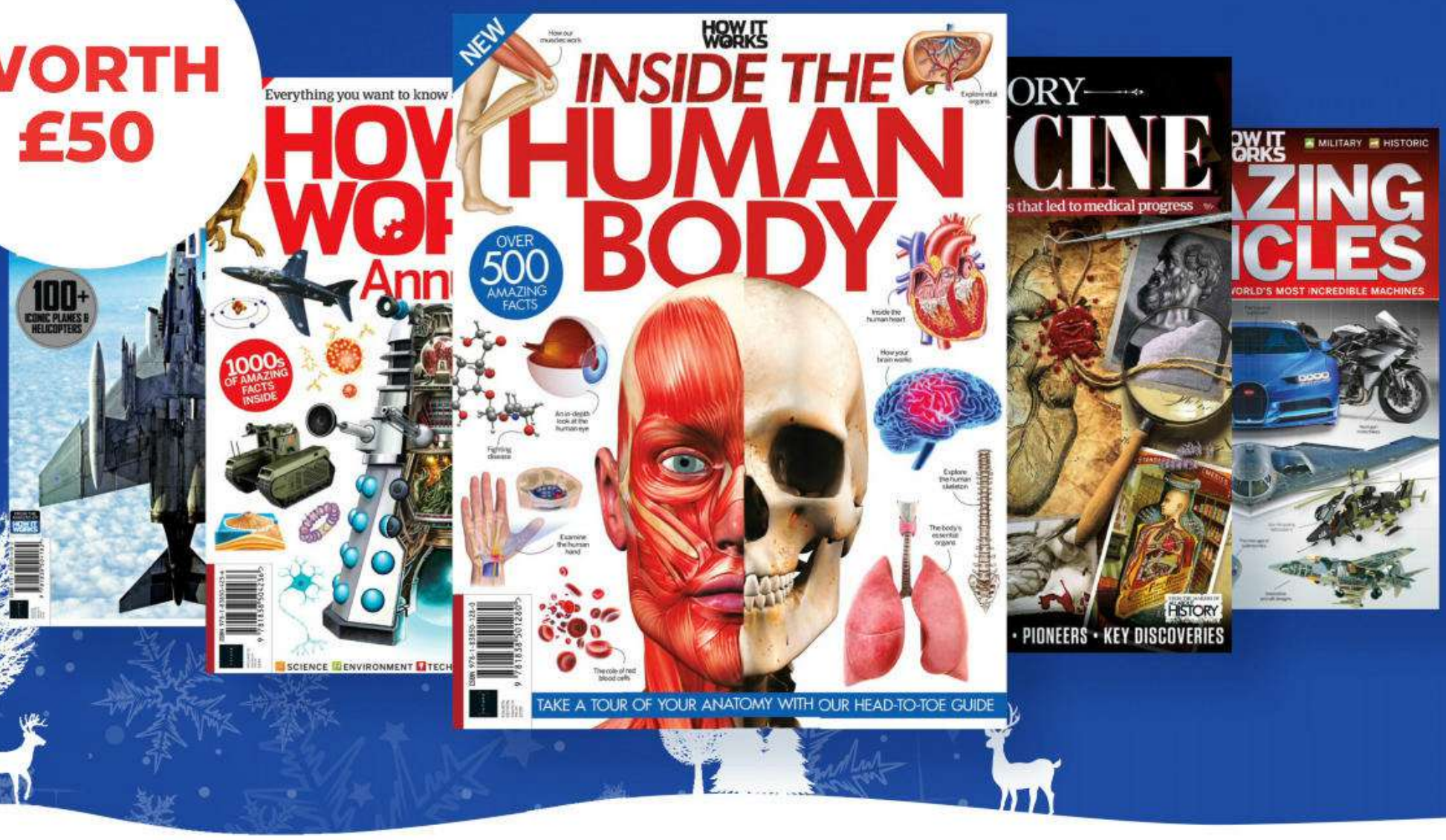

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INSIDE A VIRTUAL REALITY OPERATING THEATRE

VR is providing trainee surgeons with a realistic alternative to surgery

Words by **Ailsa Harvey**

The first experience a surgeon has of performing surgery can be daunting. After over a decade of education and training, can anything truly prepare you to cut through another person's abdomen or hack into their bones with a saw, with success so dependent on the precision of the movements you make?

FundamentalVR is a company aiming to make this transition easier for prospective surgeons. Using virtual reality technology, you can enter the high-pressure scene of an operating theatre from any location. Once the headset is in place and the equipment in your hands, you are transported to the theatre. All that is left is to select the procedure, and the appropriate body section is digitally displayed in front of you, ready for your first incision.

Described as "the cutting edge of a full-sensory VR experience", the platform includes realistic and accurate imagery of an increasing number of procedures, varying from precision keyhole surgery to more substantial open surgeries. Hi-tech haptics create the sense of touch, allowing you to feel the difference in body weight and texture between tissues.

The company's founders believe touch has transformed the platform, and that without it the concept feels more like a game than an

5 FACTS ABOUT VR SURGEON BENEFITS

1 Room to be experimental
The platform provides the safety to learn from mistakes. Surgeons can visualise the body's response to actions without causing damaging consequences to a patient.

2 Measuring performance
A data dashboard provides feedback in real time. Difficulty levels vary the assistance supplied, while quizzes test knowledge.

3 Fewer restrictions
Trainees can struggle to find experts to teach them. VR surgery allows lone practice that can be watched later by experts.

4 Rare surgery practice
Some procedures rarely occur in real-life training. VR means surgeons can practise without waiting for these rare cases.

5 Collecting points
Once a surgeon is qualified, 50 points have to be acquired annually to continue practising. These can be acquired through talks, workshops, etc. The Royal College of Surgeons has accredited FundamentalVR as a source of points.

"The cutting edge of a full-sensory VR experience"

Creating a realistic experience

An extensive team works together to create the ultimate surgical experience; from the hospital sounds and imagery creating the atmosphere, to the real-feel haptics providing texture and weight to body parts.

The talented team consists of production experts and experienced medical specialists who pass on their knowledge. Artists and haptic engineers work closely with these professionals to generate the most accurate and realistic experience possible.

Working with medical specialists around the world, advice and feedback is given to the designers and creators, who break down the procedure to make each step as close to reality as possible. Surgical specialists guide the team, test equipment and pinpoint areas where accuracy can be improved.

This feedback is mainly revised by the team of haptic engineers. The meshes used to create the sense of touch are altered and connected to the relevant 3D models. Educational medical specialists also play a role to ensure learning objectives are met.

'Multiplayer' settings are being worked on to enable surgeons to work together as they would in real life


© FundamentalVR

Q&A

VR surgery

Technologist Richard Vincent discusses this innovative training platform

What inspired you to take surgery training into the VR world?

We saw what VR was starting to suggest it could do five years ago and decided to look into it. There are lots of applications for VR, but which ones actually make a difference? One with the biggest human and business potential was in medicine. Like most people in the industry in the 1990s, we tried VR. It was pretty heavy and clunky, there were poor graphics and it was expensive. In 2014 the VR market reemerged – and that was the catalyst for FundamentalVR.

Who is currently using FundamentalVR?

It's in various hospitals and universities in London, the US, Germany, Australia and Korea. It's still got a long way to go, but they're adopting it. The medical industry is very reserved – they want lots of proof points. Everyone wants to innovate, nobody wants to go first. Validation and accreditation are big for us. Having the Royal College of Surgeons' accreditation on the whole platform tells people it's got to be good.

How does it adopt to different procedures?

Immersive technology can go pretty much anywhere. You can do orthopaedic [muscle and skeleton] hard tissue procedures and… minute, very sensitive eye surgery, using the same hardware. We're teaching surgeons of the developing world how to do cataract replacement and highly experienced surgeons a new gene therapy. It's immensely flexible.

How can VR can make surgeons better?

Surgeons learn quicker in our environment. That… is a useful thing, given the shortage of surgeons in the world. It doesn't have to be real life: it has to be good enough to teach you how to do it in real life. Some situations could feel slightly different, but is it teaching you the difference in texture and the changes in tissue behaviour? If the answer's yes, it's doing the job we want. Our mission is about putting this in arm's reach of every surgeon.


VR technology will enable surgeons to learn faster, practise more and receive better feedback from experts

© Getty

educational tool. It took around one year to produce this core technology.

Vital uses for the haptics include surgical procedures that cannot be seen when performed and require the surgeon to feel what they're doing. When cutting through bones, the platform is engineered to mimic the feel of the bone against the saw, screwdriver or drill. Additionally, when using tools to lift material from the body, the resistance placed on the haptic arms creates a sense of the weight the surgeon is pulling.

> *"FundamentalVR has incorporated realistic blood-spurting, an alarming but accurate effect"*

The technology is intended to provide the closest experience to practising on a live body. While manikins (detailed mannequins used in medicine) and sawbones have uses, once cut they cannot be reused. Meanwhile, operations on real corpses have the drawback of not producing live blood. FundamentalVR has incorporated realistic blood-spurting, an alarming but accurate effect in the case of a severed artery.

The headset's spatial awareness enables users to choose their position and move their head to obtain a clear view, exploring the incision from different angles. In real-life training, surgeons might only be able to view these procedures from obstructed positions – mainly the view of the back of a qualified surgeon's head.

The future of VR surgery

Virtual replication of a body is one thing, but imagine being able to recreate a specific patient's operation; to practise countless times before the operation day. This is one possible progression with the download of patient-specific rehearsals.

Once installed, multiple surgeons could have a go at any of the day's operations. If a rare or difficult procedure takes place, other surgeons will be able to download the data afterwards and see if they can master it.

Gloves are also currently being worked on that will enable surgeons to touch and feel the insides of their virtual patients through their fingers. Using the current technology, VR procedures such as knee surgeries are further from real life: many want to hold the knee with the other hand to steady it. In the near future, haptic gloves will allow this, making VR even more hands-on.


The imagery could soon be transferred to headsets already on the market, allowing anyone to view surgical steps at home

The platform in action

The surgical graphics, haptic computers and immersive headset work together to recreate procedures and track progression

X-ray view
Some operations require the use of additional x-ray screens. These show tools' movement in the bones in real time. Data records the time spent looking at the screen and down at the hands.

Step-by-step procedures
Looking up from the incision, screens show available procedures and steps. The body automatically resets for unlimited practice of individual procedures.

Tool selection
Some settings don't correct a wrong tool selection. As in real life, when things go wrong the surgeon must amend any negative consequences to the patient's body.

Optional prompts
A variety of difficulty levels lead up to zero guidance. Some provide instructions and guidance lines showing the angles to hold tools at.

Headset
The boxed eye mask covers full peripheral vision. While the viewing screen presents a selected image, the headset imagery shows the full viewing range.

Controlling the screens
Educational screens are controlled when looked at; a cursor appears on the screen that follows your head's movement to make selections.

Selected viewing screen
The screen shows the main section the headset is facing. This allows tutors to monitor what is happening without being immersed.

Earpieces
The sounds created by tools are replicated. This improves a trainee's awareness of changes in bone and tissue and improves authenticity.

Geomagic haptic arms
Moving the haptic arms controls the virtual tools. Some procedures require both arms to be used in order to control different tools simultaneously.

Haptic engine
This complex device monitors what body materials the virtual tools are touching. The mesh then replicates the resistance and texture to mimic the feeling against the tools.

Tool selection
The ends of the haptic arms are designed to fit 3D-printed surgical tools. Plugging them in provides a more realistic feel for the equipment.

Camouflage: how humans can hide

These animal disguise techniques have inspired cool technology

Covered in camouflage panels, soon you may not be able to distinguish helicopters from clouds

© BAE Systems

Camouflage is a tactic naturally used by animals to reduce their visibility and blend in with the surrounding environment. But while animals use their camouflage to become undetectable to predators, humans have taken inspiration for both recreational and military purposes.

Adapting to the colour, temperature and terrain of the world's landscapes, new camouflage technology is being installed in military vehicles. The purpose, not dissimilar to that of animals, is to conceal their presence from the enemy.

Battlefield conditions have no limitations, with military operations taking place in areas as diverse as deserts, forests and populated towns. Acknowledging this variety, BAE Systems has designed a flexible camouflage system to work in a range of environments.

The system, called ADAPTIV, enables vehicles to mimic surrounding temperatures, bypassing thermal detectors, and transform properties to suit the changing terrain. They can even imitate objects such as bushes, rocks and animals. And just as chameleons send visual warning signs to predators, these vehicles can display text to signal peaceful intent to civilians and allies.

To achieve these effects, the vehicles' surfaces are covered in hexagonal cells, called modules. The modules can change temperature and display a range of patterns. The mechanism can also be used to control cells individually.

Tricking the enemy in war is not a new concept. Some soldiers started wearing khaki uniforms in the 19th century, while in World War I vehicles and buildings were painted with stripes and shapes, inspired by animal patterns, to stay hidden from enemy soldiers. Now, technological advancement has opened up far more effective possibilities.

While military applications are the main focus, camouflage is used in other areas, including architecture. Tower Infinity in South Korea was given building permission in 2013. The 450-metre-tall skyscraper will activate hundreds of LED screens on one side of the building connected to cameras on the other side. These will project images of the view behind the tower, making the skyscraper 'disappear' – but only from certain angles.

Chameleons of the sea

© Getty

Octopuses are just one example of animals using disguises. Using the ability to colour-match to their surroundings, predators have a tough job when it comes to finding them.

Octopuses are sometimes called 'chameleons of the sea' because of their camouflaging skills. In addition to hiding, octopuses have developed other uses for this trait. Their colourful displays attract mates and send warning signals to other octopuses.

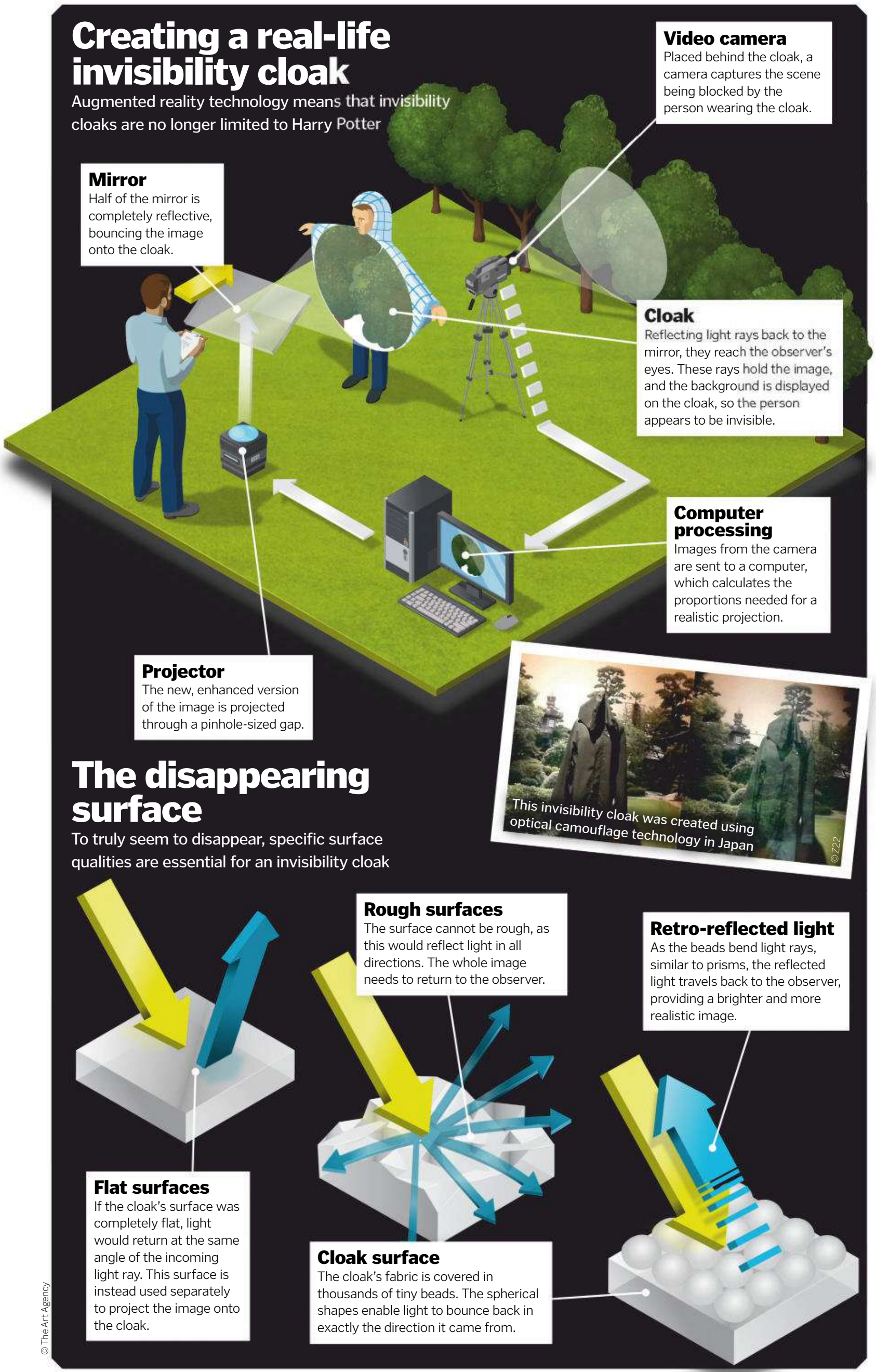
How has evolution produced this beneficial quality? Under their skin, octopuses have chromatophores – thousands of colour-changing cells. When an octopus decides to change colour, the signal is given from the brain and a stream of colour ripples through the cells in its body. These colour changes occur almost instantly.

A heat signature camouflage system demonstrated off (main image) and on (inset right) - where the tank looks like a car to an infra-red camera

x2 © BAE Systems

Creating a real-life invisibility cloak

Augmented reality technology means that invisibility cloaks are no longer limited to Harry Potter



Video camera
Placed behind the cloak, a camera captures the scene being blocked by the person wearing the cloak.

Mirror
Half of the mirror is completely reflective, bouncing the image onto the cloak.

Cloak
Reflecting light rays back to the mirror, they reach the observer's eyes. These rays hold the image, and the background is displayed on the cloak, so the person appears to be invisible.

Computer processing
Images from the camera are sent to a computer, which calculates the proportions needed for a realistic projection.

Projector
The new, enhanced version of the image is projected through a pinhole-sized gap.

This invisibility cloak was created using optical camouflage technology in Japan

© Z22

The disappearing surface

To truly seem to disappear, specific surface qualities are essential for an invisibility cloak

Rough surfaces
The surface cannot be rough, as this would reflect light in all directions. The whole image needs to return to the observer.

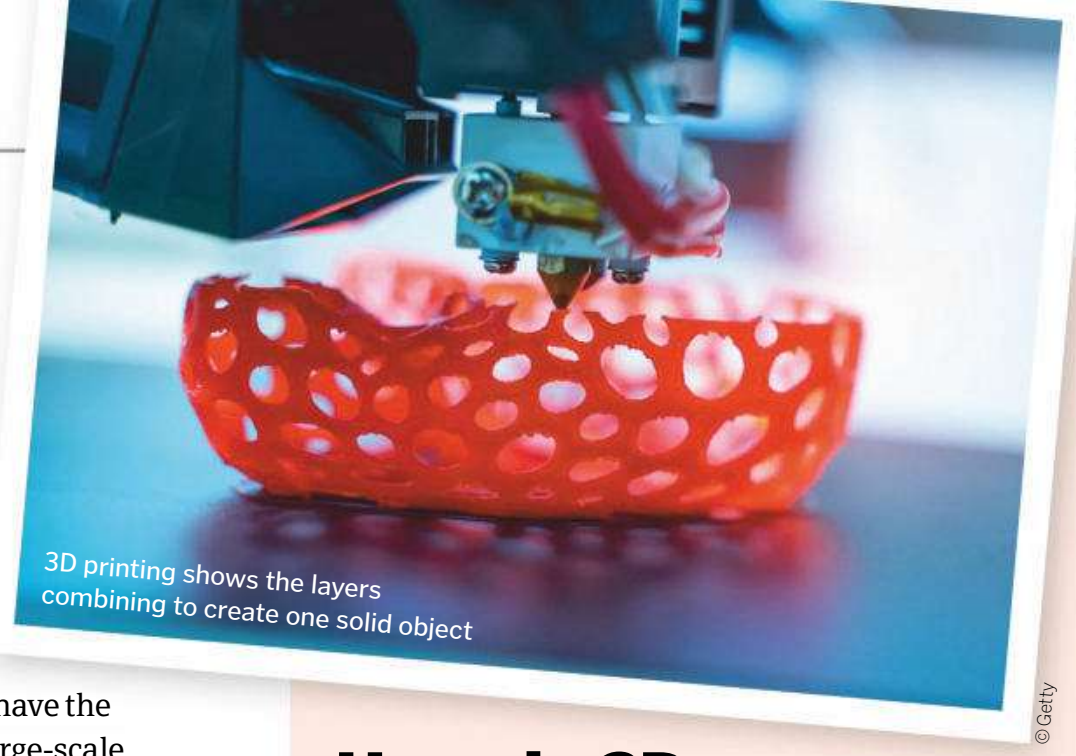
Retro-reflected light
As the beads bend light rays, similar to prisms, the reflected light travels back to the observer, providing a brighter and more realistic image.

Flat surfaces
If the cloak's surface was completely flat, light would return at the same angle of the incoming light ray. This surface is instead used separately to project the image onto the cloak.

Cloak surface
The cloak's fabric is covered in thousands of tiny beads. The spherical shapes enable light to bounce back in exactly the direction it came from.

Inside 3D printers

This technology originated in the 1980s and has reduced manufacturing time from days to hours



3D printing shows the layers combining to create one solid object

© Getty

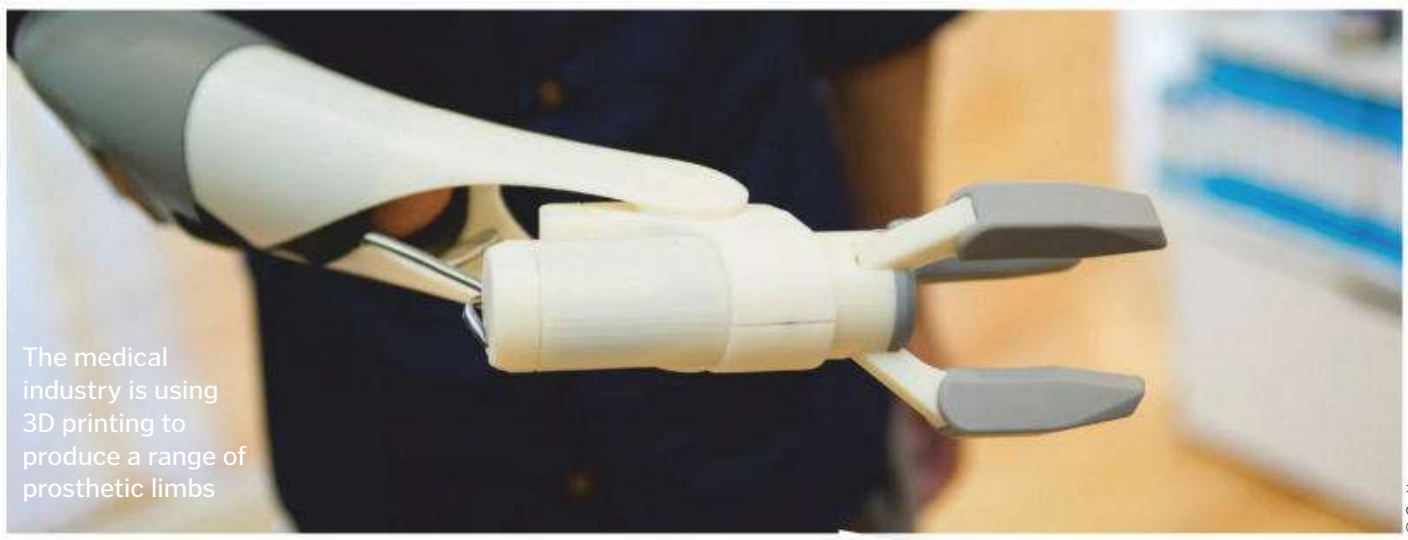
The spectacle of 3D printing has left many in a state of wonderment. As if by magic, a virtual, on-screen design can be built in front of us at the push of a button, transformed into a three-dimensional, solid object. 3D printers' efficiency in creating detailed designs means that, layer by layer, almost any object can be produced – from the cheap mass production of engineering tools to fashion accessories and novelty toys.

With design work being completed on a computer, this information is passed on to the printer, which interprets the data for manufacture. Breaking down the design into a series of cross-sections, the printer works to weld each layer at various intricacies of different scales, until the final product has been produced. This layering process is called additive manufacturing.

As materials available for 3D printing are expanding, so are the applications. One day we could all be printing products from our homes; buying the necessary materials to personalise anything we could possibly need. While more people will have the ability to make more things, large-scale applications such as aircraft engineering and architecture will still be limited to those with professional expertise and resources.

But before skipping ahead to what is yet to come, it is worth looking back to when this idea first arose. Japanese inventor Hideo Kodama made the first innovations in layering for 3D printing in 1981. His invention involved a device that solidified photo-reactive polymers using UV light. This shed light on the future of what three-dimensional design could do.

3D printing stems from this invention, as it gave rise to many design possibilities. From this came the speedier design of prototypes and models. Stereolithography is one of the most common 3D printing techniques used today and heavily resembles the work of Hideo Kodama.



The medical industry is using 3D printing to produce a range of prosthetic limbs

© Getty

Out of this world

One of the greatest features of 3D printing is its ability to use a selection of core materials to produce a variety of designs on the spot. This use could prove to be a valuable asset in future space travel. Based here on Earth, we are surrounded with the equipment and materials required for the majority of manufacturing scenarios. But what happens if you are millions of kilometres away from civilisation?

3D printers are currently being tested by NASA, recognising the value of this concept for space missions. For space exploration, it is essential that the tools needed are to hand. But anything can go wrong on a spacecraft and relying on shipments from Earth delays progression of space missions and could mean the difference between failure and success.

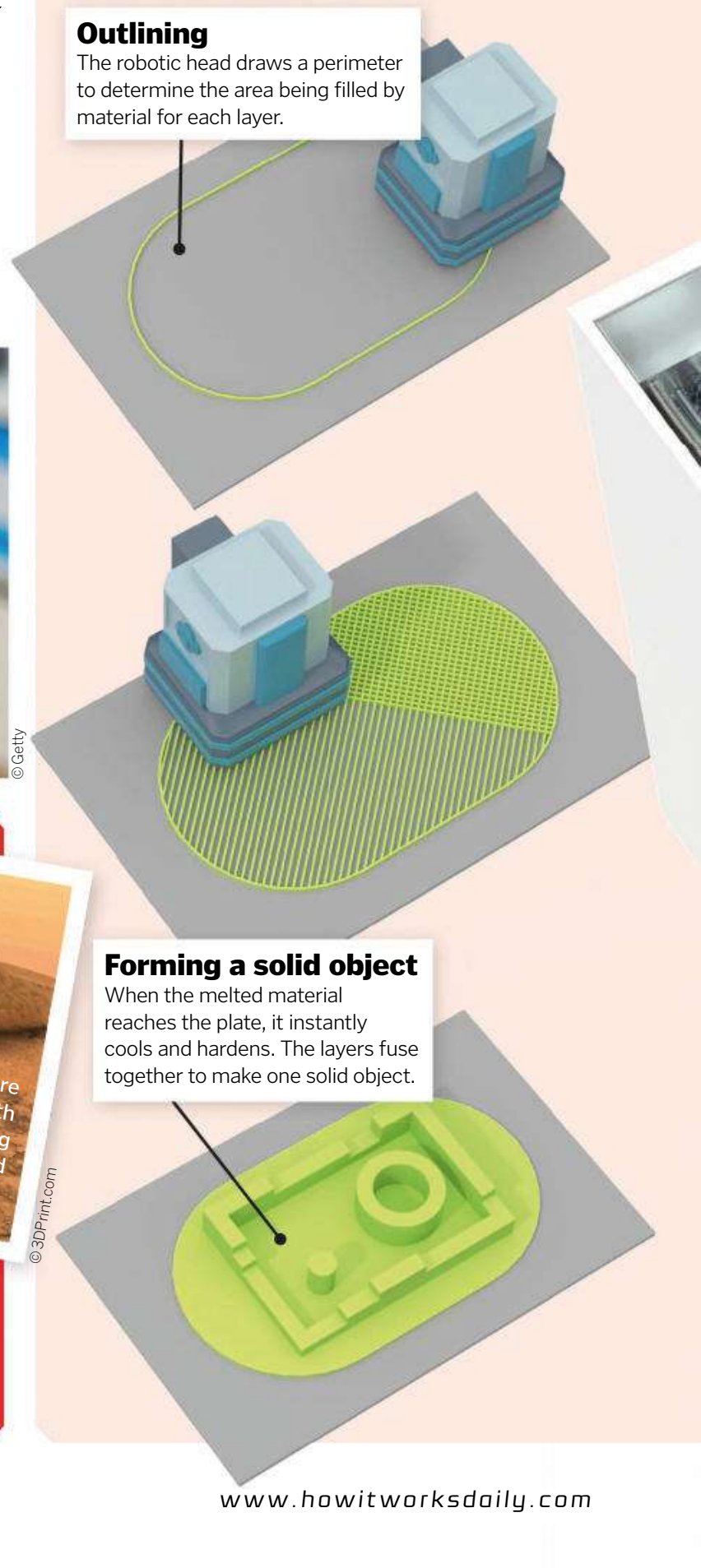
In the future, astronauts could print their own equipment as and when they need it – an instant solution. And why stop at tools? Using material from other planets, such as the sandy surface of Mars, we could be building houses on the Red Planet using this technology.

Scientists are experimenting with 3D-printed building designs to withstand extreme conditions found on other planets

© 3DPrint.com

How do 3D printers work?

Manipulating the temperature of thermoplastic materials enables these printers to produce unlimited 3D shapes and designs



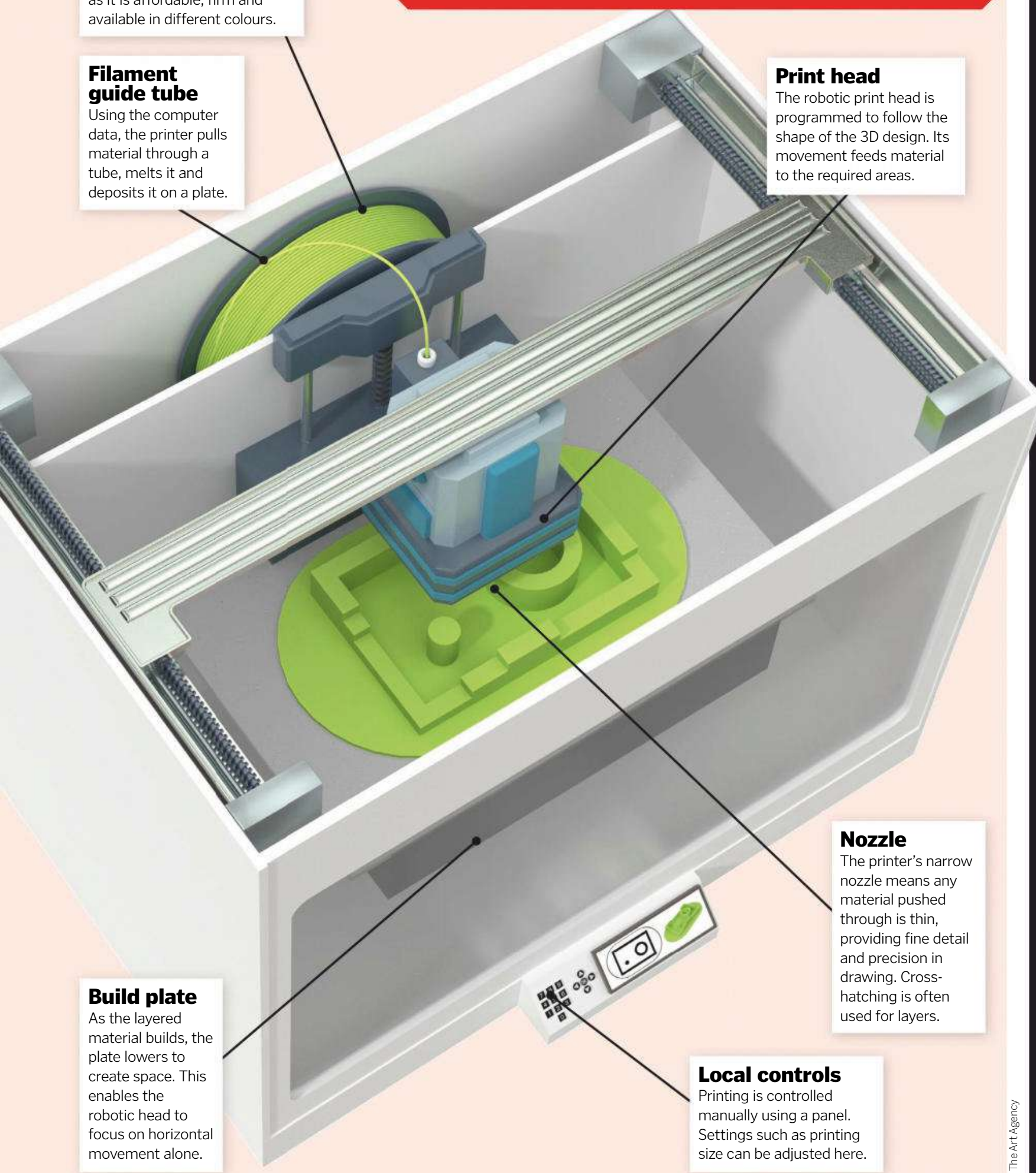
"We could be building houses on the Red Planet using this technology"

A toy that changed 3D printing

The most popular 3D printing method is fused deposition modelling (FDM). Thermoplastic polymers are melted and squeezed through a nozzle to form thin strands: this builds the shapes through layering.

FDM was thought up by Scott Crump as he was designing a toy frog for his daughter. To create it, he used a glue gun loaded with polyethylene and candle wax. Fusing the layers together, he followed a process of building the animal from the bottom up, a layer at a time.

While he could have gifted the frog and thought no more of it, this was the catalyst that sparked the fundamentals for wide-scale production of plastic prototypes. Who would have thought such a trivial project would give rise to the advanced tools that are today's 3D printers; assisting the developments in industries such as health, engineering and space?



Material reel
Printing material is fed into the printer from a spinning reel. Plastic is most commonly used as it is affordable, firm and available in different colours.

Filament guide tube
Using the computer data, the printer pulls material through a tube, melts it and deposits it on a plate.

Print head
The robotic print head is programmed to follow the shape of the 3D design. Its movement feeds material to the required areas.

Nozzle
The printer's narrow nozzle means any material pushed through is thin, providing fine detail and precision in drawing. Cross-hatching is often used for layers.

Build plate
As the layered material builds, the plate lowers to create space. This enables the robotic head to focus on horizontal movement alone.

Local controls
Printing is controlled manually using a panel. Settings such as printing size can be adjusted here.

© The Art Agency

New projects

Applications continue to grow, with products from luxury items to life-enhancing tools being created with 3D printers

© Unseen Art

Art for the blind

Unseen Art used 3D printing to give those who can't see the chance to appreciate art through touch. Programming printers recreated 3D Mona Lisas, enabling the blind to experience the masterpiece.

© IACC

Printing architecture

On a larger scale, within a Madrid park stands proof of architectural 3D printing. Using a special type of binding sand, the creators produced this 12-metre-long pedestrian bridge.

© Getty

Bioprinted body tissue

Using human tissue, 3D printing is being used to produce body parts and organs. Printed ears and noses have already been transplanted, and now miniature hearts are being printed.

© FoodLink

Futuristic food

Edible 3D printing is increasing food creativity. Food Ink described itself as the world's first 3D-printed restaurant. Customers sat at 3D-printed furniture and enjoyed 3D-printed food.

RISE AN

DID YOU KNOW? *Over 5,000 East Germans, including 600 border guards, managed to cross the wall and defect*

WHEN IT FELL

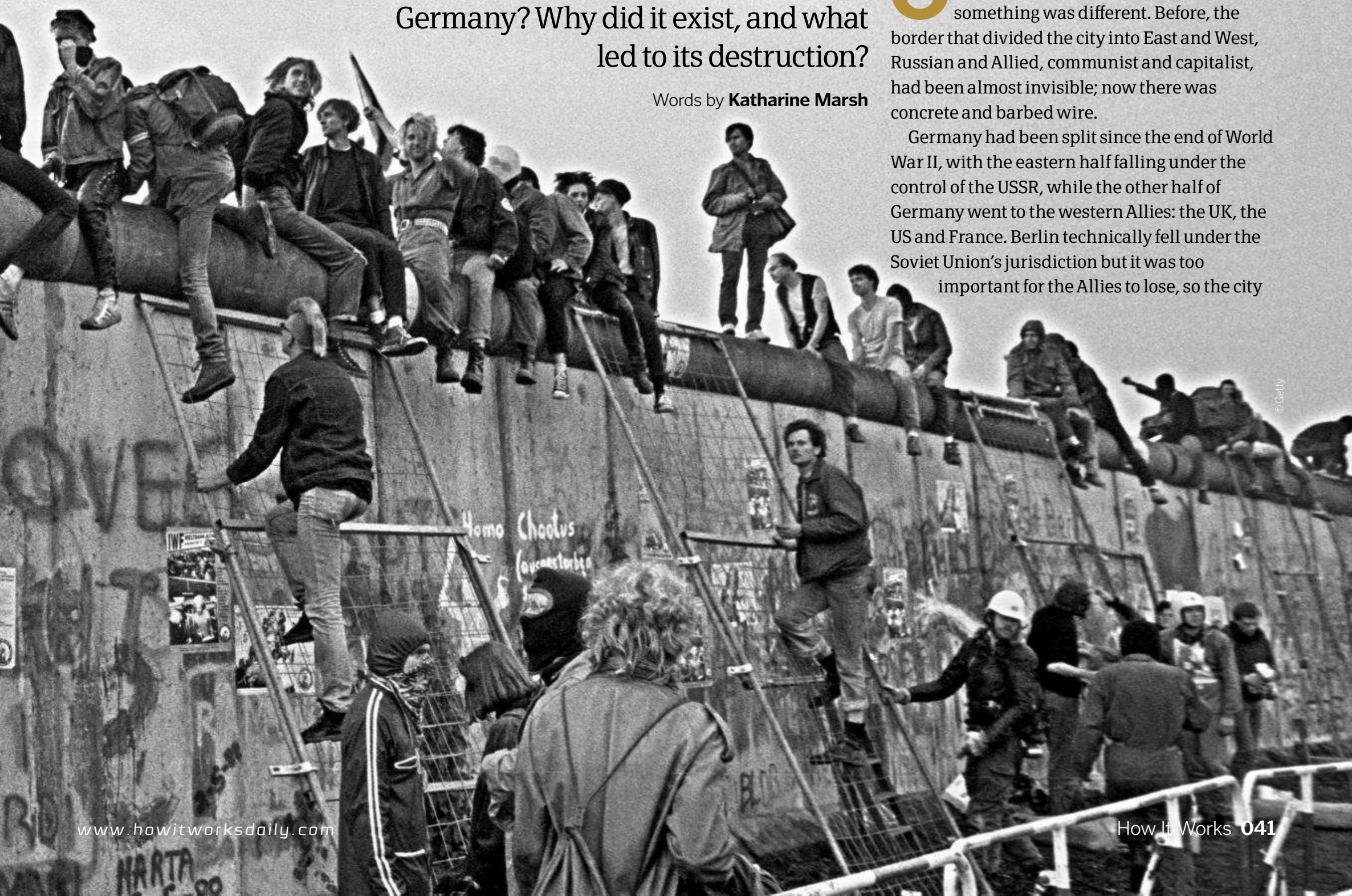
THE BERLIN WALL

What was this symbol of Cold War Germany? Why did it exist, and what led to its destruction?

Words by **Katharine Marsh**

On the morning of 13 August 1961, Berliners woke up as normal. But something was different. Before, the border that divided the city into East and West, Russian and Allied, communist and capitalist, had been almost invisible; now there was concrete and barbed wire.

Germany had been split since the end of World War II, with the eastern half falling under the control of the USSR, while the other half of Germany went to the western Allies: the UK, the US and France. Berlin technically fell under the Soviet Union's jurisdiction but it was too important for the Allies to lose, so the city



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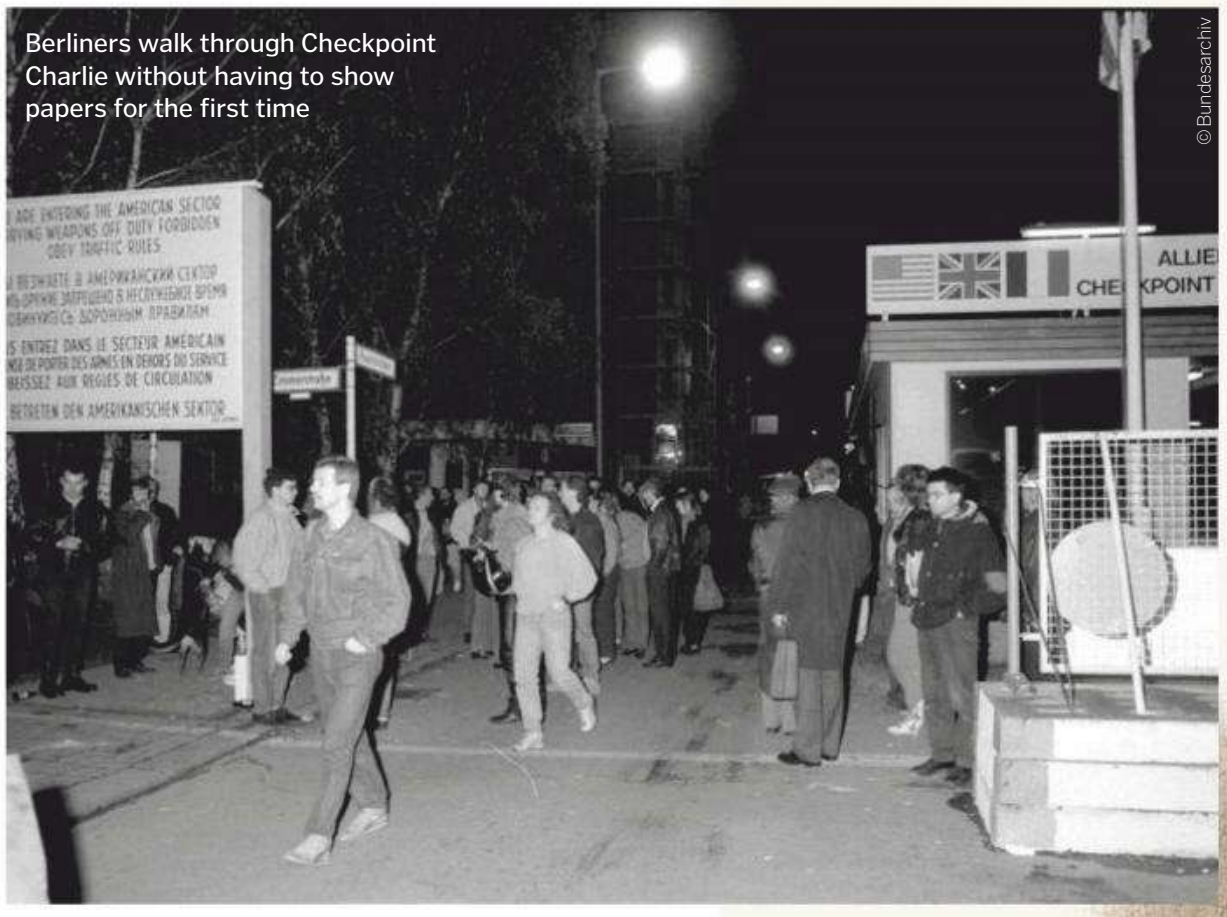


Berliners walk through Checkpoint Charlie without having to show papers for the first time

© Bundesarchiv

was split too. Citizens from East and West would cross the border to work, go to school, do some shopping and visit the theatre or cinema. They lived unhindered, but change was in the air.

The existence of capitalist West Berlin in the middle of communist East Germany "stuck like a bone in the Soviet throat", according to USSR premier Nikita Khrushchev. The Russians wanted the capitalists gone and so they tried to starve them out in 1948 by blocking access to Berlin. This lasted for over a year, but it was to no avail – the Allies delivered more than 2.3 million tons of food, fuel and other goods by air. A decade of calm followed, but it wasn't to last.

In those ten years, 3 million refugees had defected to the West, including doctors, teachers and engineers. The USSR was losing these much-needed people in the midst of the Cold War – they were just walking over the border. Summits and conferences to solve the problem came and went but no progress was made. In June 1961, around 19,000 people left East Germany through Berlin. The next month, it was 30,000. The first 11 days of August saw 16,000 more, and then on 12 August, another 2,400 – the highest number of defectors to leave East Germany in a single day.

© Getty

"Tear down that wall!"

The western world was against the wall, and in 1987 President Reagan demanded that the USSR bring it down.

Germany divided

Take a whistle-stop tour along either side of Berlin's Iron Curtain

Checkpoint Charlie

Perhaps the most famous of all the checkpoints along the Berlin Wall, Charlie saw many attempted defections by East Germans.

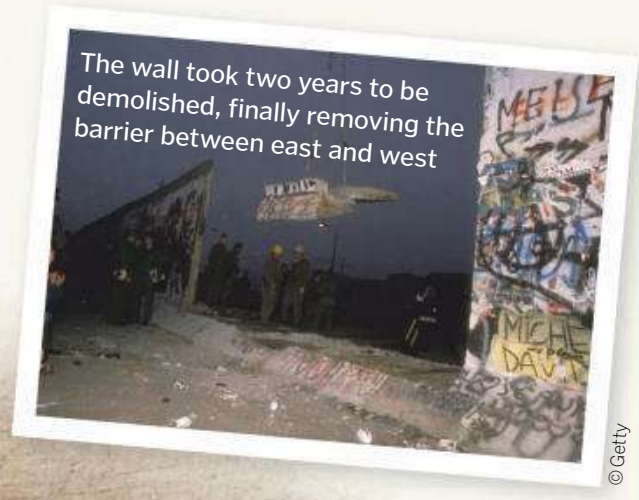
Making the crossing

Trying to cross the wall meant almost certain death, but that didn't stop people from trying. Over 30 years, hundreds were killed.

Always watching

In total, there were 302 watchtowers by the time the Berlin Wall fell in 1989.

Wall version 1.0
The original wall was constructed of barbed wire and cinder blocks, and took about two weeks to build.


The wall took two years to be demolished, finally removing the barrier between east and west

© Getty

Mauerpark
Originally part of the border, Mauerpark is now a public area and was opened in 1994, exactly five years after the Berlin Wall fell.

The Death Strip
The Berlin Wall was supposed to be impregnable – but that didn't stop people from trying to get into West Berlin. Some tried to escape through sewers, others by driving through unfortified parts of the wall at high speed. Then there were those who tried to walk.

Between the two walls that made up the Berlin Wall there was a strip of land that became known as the Death Strip. Soft sand on the ground showed footprints of any possible refugees, but they were usually found before the guards had to rely on this method. The area was floodlit, and patrolling soldiers with vicious dogs had orders to shoot on sight. There were even trip-wire machine guns.


Attempting to cross the Death Strip would almost certainly end in death

© BeenAroundAWhile

The East Side Gallery
A 1.3-kilometre-long memorial, this open-air gallery, the longest extant section of the wall, has been painted by 118 artists from 21 countries.

No climbing
Standing at five metres tall in some places, it was almost impossible to climb. The barbed wire and large pipes along the top didn't help.

Baumhaus an der Mauer
On a bit of derelict no-mans land by the wall, Osman Kalin built a treehouse in 1983. Border guards inspected it, but ruled that it was okay. It still stands today.

"Patrolling soldiers with vicious dogs had orders to shoot on sight"

© Nicholas Forder

East and West Berliners are reunited in front of the Brandenburg Gate

© Getty

A Mauerspechte, or wall woodpecker, chips away at the Berlin Wall in November 1989

© Skäpperöd

East vs West

© Getty

West Berliners enjoyed a life full of theatres, nightclubs and shops, while those in East Germany were living under a failing economy with few luxuries.

© Getty

While West Germans had a relative amount of freedom, the East was ruled by fear. Speaking out against the government could get you jailed.

© Getty

Pop culture was all but banned in East Berlin, with the secret police keeping track of anyone who appeared to show any signs of "degenerate Western trends" such as the punk movement.

The Berlin Wall was demolished section by section to bring East and West Germany closer together

© Getty

"It was called the greatest street party in the world – everyone was drinking beer and champagne"

Bricks in the wall

The wall came to symbolise a worldwide ideological struggle

1945

After Germany's defeat in World War II, Berlin and Germany are both split in two, with one half controlled by the USSR and the other by the Allied nations.

May 1949

On 12 May, the Federal Republic of Germany, or West Germany, is founded. The German Democratic Republic, or East Germany, is founded 12 days later.

August 1961

The construction of the Berlin Wall is ordered on 13 August, and the first version is completed in just two weeks.

June 1963

US President John F Kennedy makes his famous anti-communist speech in West Berlin on 26 June and claims, "Ich bin ein Berliner."

The Warsaw Pact

What do you do when you're worried about being attacked or invaded? You make a pact. On 14 May 1955, the Soviet Union, Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland and Romania all came together in the Treaty of Friendship, Cooperation and Mutual Assistance, otherwise known as the Warsaw Pact (although some of those countries did join a little later). A direct opponent to NATO (North Atlantic Treaty Organization), which was signed between western European countries, the US and Canada, it created an alliance so that if one nation came under attack, the others would all come to its aid. The pact also placed a strong emphasis on non-interference in internal affairs, so countries were free to go about their business – though in reality, the USSR ruled the roost.

But while NATO is still going strong today, the Warsaw Pact saw its demise in 1991. East Germany had left in September 1990 so that it could reunite with West Germany, and Czechoslovakia, Hungary and Poland all dropped out the following month.

The wall sprang up overnight, and the East German army, police force and volunteer workers all helped to finish it over the next fortnight. Suddenly, it was impossible to cross the border without going through one of three checkpoints: Alpha, Bravo and Charlie. There, East German soldiers would screen diplomats and other officials, but the general public couldn't cross. The rushing river of refugees was halted in its tracks. Trying to sneak across was not an option unless you wanted to be gunned down. US president John F Kennedy wasn't happy about the situation, but he did concede that "a wall is a hell of a lot better than a war".

Over time, the original small wall was replaced with one that was taller, sturdier and harder to climb. Berlin was now officially two cities existing side by side, never really seeing the other. As always, life went on. For almost 30 years, East and West stayed separate.

But walls don't last forever. On 9 November 1989, a spokesman for East Germany's Communist Party made an announcement: starting immediately, citizens of East Germany would be free to cross the border. Berliners from both sides flocked to the wall, eager to see friends, family and history in the making. It was called the greatest street party in the world – everyone was drinking beer and champagne, all chanting "Tor auf!" or "Open the gate!" Later that night, they flooded through.

Hammers were used to knock away chunks of the Cold War's most recognisable symbol, and later cranes and bulldozers pulled down huge sections of the wall. Germany was reunified almost a year later, the East German government unable to stay in control any longer.


People flood to the wall to celebrate the two halves of Berlin finally rejoining

© Getty

2
Berlin and Germany were split into two separate parts

43.1km
The length of the border between East and West Berlin

239
The highest estimate of people killed trying to cross the wall

2,400
The number of East Germans who defected to the West the day before the wall was built

10,315
The number of days the Berlin Wall stood as a barrier between East and West

1973
East and West Berlin finally establish some formal diplomatic ties, and an agreement is made to ease some travel between the two.

June 1987
On 12 June, US President Ronald Reagan's speech asks Mikhail Gorbachev, the general secretary of the Communist Party, to "tear down this wall."

October 1989
Mass anti-government demonstrations, called the Monday demonstrations, are held across East Germany.

4 November 1989
More than 1 million people attend the Alexanderplatz demonstration calling for democracy in East Germany. The government soon resigns.


© Wiki

9 November 1989
Thousands of East German protestors demand to be let through the checkpoints after a government spokesman messes up at a news conference. The wall is breached and days of celebrations follow.

October 1990
Almost a year after the fall of the Berlin Wall, East and West Germany reunite to become the Federal Republic of Germany.


© Wiki

©Alamy

How to survive a Victorian school

Classrooms in the late 1800s were very different from today: here are a few ways you could have avoided the dreaded cane

Address the teacher properly

School teachers in Victorian times were usually local, unmarried women. Referred to as 'miss' to indicate her marital status, once the teacher was married she would usually quit her job to become a housewife. There were also some men who entered teaching roles. They typically held positions in high-achieving private schools, but due to the low pay, most men steered away from most classrooms.

Unlike the rigorous training and education teachers undergo today, Victorian educators were not college graduates and simply learned on the job. Teachers were not known for their patience and understanding and were not shy about using physical disciplinary action.

Learn fast and follow the rules

The iconic dunce cone was awarded to those that didn't learn as quickly as other students. However, although sitting in the corner wearing a paper cone bearing the letter 'D' might make you feel like a fool, there were many other, much harsher ways in which Victorian teachers maintained order. Grasping either a wooden cane or a bundle of birch branches, it was common for teachers to beat unruly children for bad behaviour. Typically, boys were struck on the backsides and girls were caned on the hands and legs. Between the ages of five and ten, anything from laziness to truancy would land you in the firing line for physical punishment.

Remember the three Rs

A far cry from the wealth of subjects that pupils can study today, back in the 1800s topics of study were limited to Reading, wRiting and aRithmetic – the 'three Rs'. Religious studies, however, joined the classroom later to make the educational trio a quartet. Using the Bible as a common reference material, children would recite passages to develop their reading and writing skills.

The study of arithmetic was delivered in a similar way to today, reciting times tables and calculating simple sums. It differed, however, with the use of the imperial weights and measures system of the Victorian era. For example, there were 240 pennies in a British pound, weights were measured in pounds and ounces and distances were measured in yards and furlongs.

Don't write with your left hand

During the Victorian era Christianity informed a pupil's education, even down to the hand they wrote with. In the Bible, Christ is referred to as the right hand of God, while Lucifer (the devil) is associated with his left side. Because of this, writing with your left hand was seen as an unholy act, resulting in teachers binding the left hand of any children caught doing so behind their backs, forcing them to use only their right hand.

©Getty

'Ragged schools' vs private education

Compulsory school attendance was introduced in the United Kingdom in 1880 under the Education Act. Before this, education was predominantly only available to those families that could afford it. Male family members attended private schools and females were schooled by governesses in their homes.

However, across the country, church and volunteer-staffed schools were available for poorer families. By 1870 there were around 350 of these charitable schools, also known as 'ragged schools', across the UK. Although free to attend, poor families couldn't afford to lose the potential income children could earn working, and so many poor children were still denied education.

©Getty

Public schools such as Dulwich College, London, allocated a few spaces for bright, poor students

Get to know your equipment

Wooden desks

Classroom desks typically housed a small ink well for older students using dip pens. An 'ink monitor' would be allocated to refill the well each morning.

©Alamy

Slates and chalk

Keeping school costs down, younger pupils were required to do their daily school work on slate chalkboards rather than on paper.

©GodeNehler

Abacus

With electronic calculators still about 100 years from invention, arithmetic was taught with the use of the humble wooden abacus.

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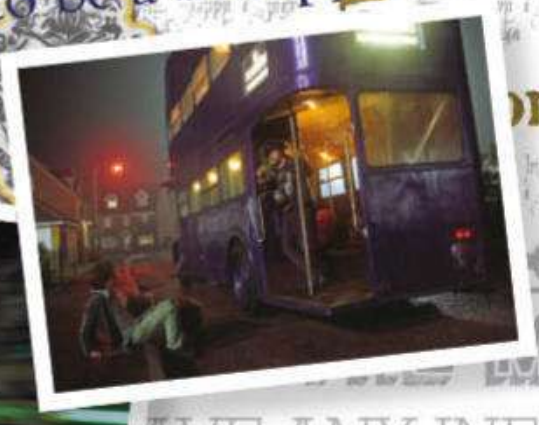

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AR ZONE!

What are totem poles?

While only specialists are trusted to carve these mighty sculptures, it takes a village to raise them

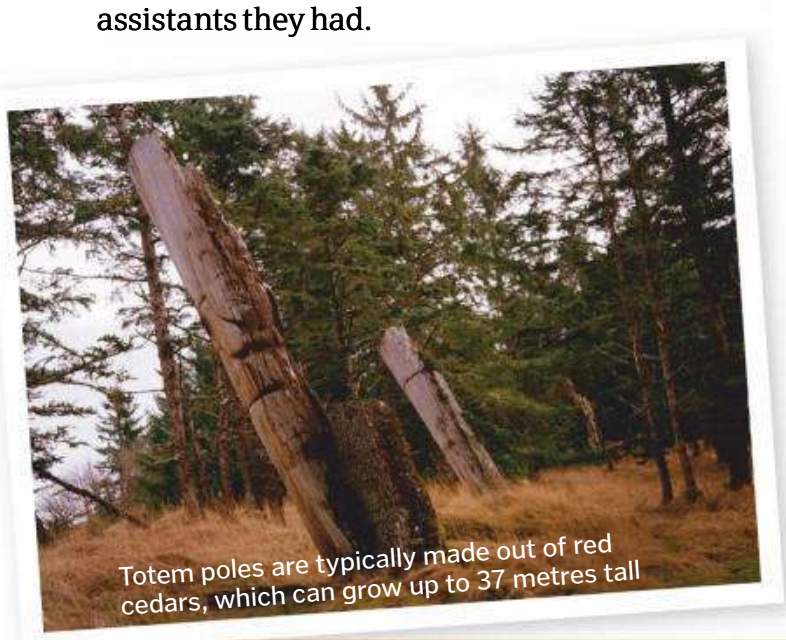
Totem poles are one of the most iconic examples of Native American art. They're found in the Yukon and British Columbia regions of Canada, as well as Alaska and Washington in the US. Created by the Northwest Coast indigenous peoples, each community has its own methods of designing totem poles. The Haida, for instance, often carve creatures with bold eyes, whereas the Kwakwaka'wakw poles typically have narrow eyes. The Coast Salish carve images of people, while the Tsimshian prefer supernatural beings on their poles.

All of them were made by skilled craftsmen. They would make totem poles out of the trunks of giant red cedars. It could take months, during which time the wealthy families that commissioned the artwork would be responsible for feeding the carver and any assistants they had.

The whole community was invited to take part in a totem pole's raising. It might take hundreds of men to carry it to the site where it would be erected. A deep trench was dug to keep the pole upright, while it was carefully put in place in stages using strong ropes and stakes. And though they weren't religious artefacts, a pole-raising would often be an excuse for a celebration. The carver would dance around the pole to the sound of drums. There might even be a feast and gift-giving.

In the northwest Pacific's mild, wet climate, few poles made before the 20th century still exist. But archaeological evidence suggests they were being carved hundreds of years before the first European explorers arrived.

Totem poles were effectively banned for over 60 years by the Indian Act in Canada in 1876. They were also forbidden under the US Code of Indian Offenses in 1884. But today totem poles are once again celebrated, with some of the tallest ever carved in the 1960s and 1970s.



Totem poles are typically made out of red cedars, which can grow up to 37 metres tall

© Getty

AR ZONE! SCAN HERE

The thunderbird
A legendary figure in many Northwest Coast cultures, this weather-controlling creature denoted power, mysticism and leadership on a totem pole.

© Adrian Mann

Types of totem

While Northwest Coast peoples mostly passed down knowledge by word of mouth, when they wanted to preserve important information a totem pole would be made. The details would be told to a carver, who would be able to visualise the right symbols and encode the story into a sculpture. This could range from who owned the rights to what territories to genealogical records.

Memorial poles honoured deceased chiefs and high-ranking members. They would depict a person's accomplishments or family history. Haida mortuary poles also honoured the dead, topped with a box containing the deceased's ashes. Legacy poles commemorated important historical events, while family poles featured animals that made up a clan's crest.

Less common were shame or ridicule poles, which criticised neighbours for being offensive or not paying their debts. Chiefs also used these poles to belittle their rivals.

A Coast Salish totem at Brockton Point in Vancouver, British Columbia

© Wiki

A curse on Virginia Water

In 1958, Canada gifted a totem pole to the queen to mark the centenary of British Columbia. Commissioned in her honour, the sculpture was 30 metres tall and weighed 12 tons. Each of its elaborate carvings representing a different indigenous clan. It was shipped to Britain via the Panama Canal and put on public display at Virginia Water Lake, Surrey. However, its chief sculptor, Mungo Martin, an eminent Kwakwaka'wakw artist, was so offended at not be invited to the pole-raising he put a curse on his creation. By way of apology, Martin and several other Kwakwaka'wakw members were flown over and invited to perform a dedication dance that lifted the curse.

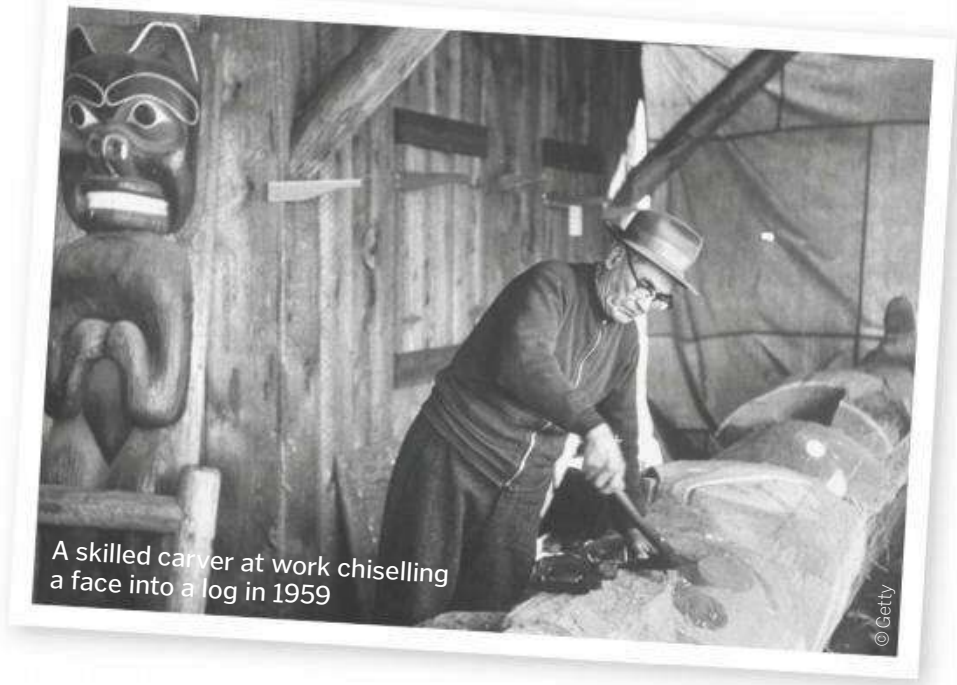
© Getty

Mungo Martin's totem pole arrives at the entrance of Windsor Great Park

The snake
While European art often depicts serpents as evil, the skin-shedding reptile represents change, medicine and fertility in some Native American cultures.

The wolf
While revered as a cunning hunter, wolves live in packs so are also often used to represent loyalty and strong family ties.

The beaver
Capable of building mighty dams, beavers symbolise both creativity and determination, while appearing in many indigenous stories.



A skilled carver at work chiselling a face into a log in 1959

© Getty

"Few poles made before the 20th century still exist"

Painted totem poles, each one carved symbolically to display a message or story

© Getty

The bear
Often featured in family crests, the grizzly bear stands for strength and authority, but also motherhood, teaching and humility.

Putting up a pole

Here's how to go from lowly log to towering totem

Select a tree
The Northwest Coast peoples favour red cedars because they're soft but long-lasting. However, you also need to find a tree that's tall, straight and free of knots, and near a river, so that it can be floated to the carving site.

Chop it down
There are different ways to fell your cedar. The easiest is to light a controlled fire at the base of the trunk. Or you could go round it several times with a chisel, maul and wedge, stripping out sections at a time.

Carve the figures
After stripping the bark, outline the design in charcoal. The most important figure should go at the bottom where people can see them. Carve using traditional tools: bone-pointed drills, stone hammers, wooden chisels, etc.

Paint the pillar
Use a paintbrush made from sea otter hairs and other fibres. Not every group paints their poles, but the two most common colours to use are red and black, traditionally made from salmon blood and charcoal.

© Ed Crooks

© Getty

DID YOU KNOW? *In some cultures, people believe that wearing red underwear will distract ghosts*

THE SPOOKY SCIENCE OF GHOST HUNTING

How It Works investigates ghostly hauntings and explores the everyday explanations behind many paranormal experiences

Words by **Joanna Elphick**

Everybody knows of a 'haunted house' in their neighbourhood, where something terrible once happened and where the spirits inhabit the empty hallways and dank, dark basements. But for some, it's not enough to walk past and wonder what foul fiends lurk behind the tattered curtains. Some people need to know more, and so, with trusty torch in hand and a rucksack full of equipment on their backs, they go where the rest of us are far too scared to stray.

Although accounts of seeking out spirits date back to 100CE, ghost hunting in its truest sense started in earnest at the beginning of the Victorian era. Early Victorians were obsessed with death and thoughts of what lay beyond the mortal realm. Ghost stories became increasingly popular, and with this new-found fascination with the supernatural came a group of serious ghost hunters, intent on proving the existence of spirits. For the first time, spooky tales were being investigated objectively, setting the general standard for all paranormal investigators to explore rational explanations before accepting the supernatural.

While women were cashing in on the new Spiritualist wave, running elaborate séances

How to take your own ghost photo

Scare your friends with a realistic image of a ghost captured on camera, just like the William Hope hoaxes

First, get your camera ready

Make sure your digital camera has a 'fireworks' mode and switch it on, or use a 'nighttime' mode without a flash so the exposure time is at least three seconds. Use a tripod so the camera doesn't move.

Set up a spooky scene

Choose somewhere indoors that is not too dark or too light but has a creepy look about it. Find someone to be your 'ghost', or alternatively you can even be the 'ghost' yourself.

Capture your ghost

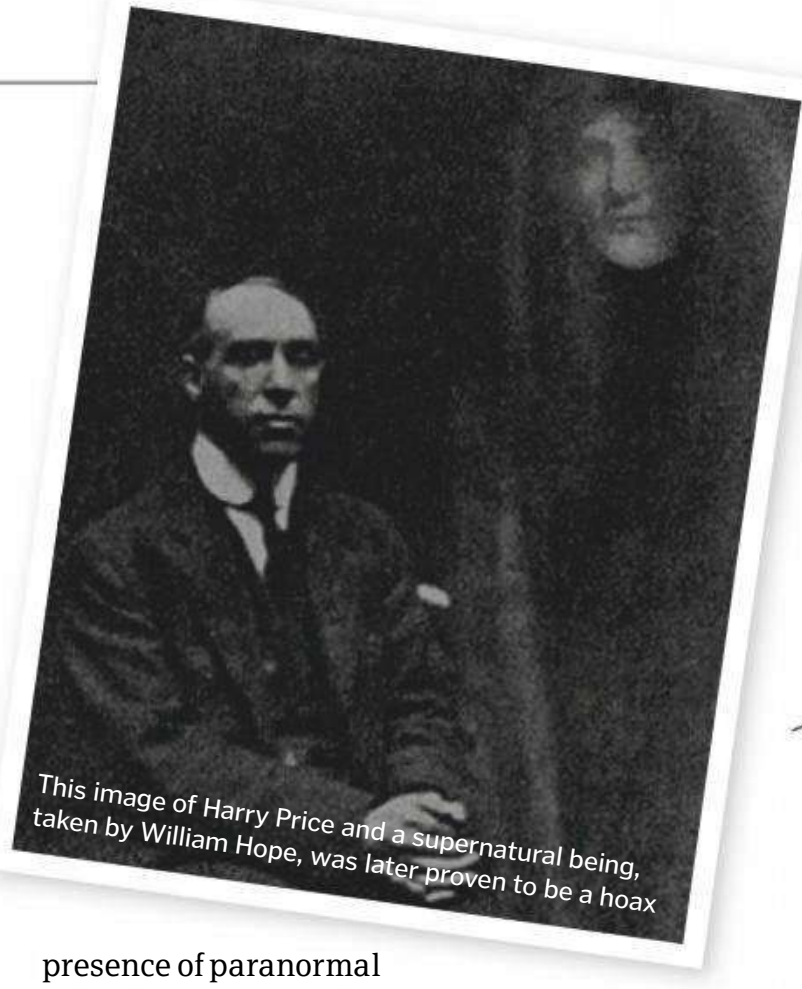
Use a timer if you want to be in the photograph yourself. Get into position. When the camera starts to take the picture, count to two then move into another position. There will be a transparent 'ghost' of you because of the exposure time.

and Ouija board sessions to 'help' people contact their departed loved ones, well-educated, professional gentlemen were setting up a variety of supernaturally themed clubs. The most prestigious of these gatherings was the Ghost Club, set up in 1862, which boasted a variety of academic members, including Charles Dickens, Sir Arthur Conan Doyle and Cambridge philosopher Henry Sidgwick.

By 1882 a new scientific approach to ghost hunting led to the creation of the Society for Psychical Research, and books and articles on the subject matter were soon available to the fascinated general public. With the arrival of the motor car, more and more ghost hunters started visiting alleged haunted buildings.

One such paranormal investigator, Harry Price, pushed for a scientific approach to ghost hunting and set up the National Laboratory of Psychical Research in 1926. Price conducted a number of investigations, the most famous being his research into the infamous Borley Rectory, and later the Chiswick Museum hauntings. He also set about debunking the influx of supernatural photography flooding the market.

With the use of his well-equipped laboratory, he revealed that many of the séances conducted across the country were in fact fake and that the substance in the photographs taken by the medium, Eva Carrière, wasn't 'ectoplasm' (a supernatural goo brought about by the presence of paranormal entities) but nothing more that bits of chewed paper. Other photographs that had been taken by William Hope were also found to be clever hoaxes.


This image of Harry Price and a supernatural being, taken by William Hope, was later proven to be a hoax

Although the fascination with the supernatural has peaked and waned over the years, it has never disappeared entirely and is more popular than ever today. In 2014, a YouGov poll found that 39 per cent of British people believe in the concept of haunted houses and 34 per cent believe that ghosts actually exist. Over 1,000 ghost-hunting clubs exist around the UK, fuelled by television programmes such as *Most Haunted* and the

"In 2014, a YouGov poll found that 39 per cent of British people believe in the concept of haunted houses and 34 per cent believe that ghosts exist"


The infamous Borley Rectory is said to have been haunted ever since it was built

Supernatural hotspots

Fancy a haunted holiday? Why not visit one of these creepy destinations?

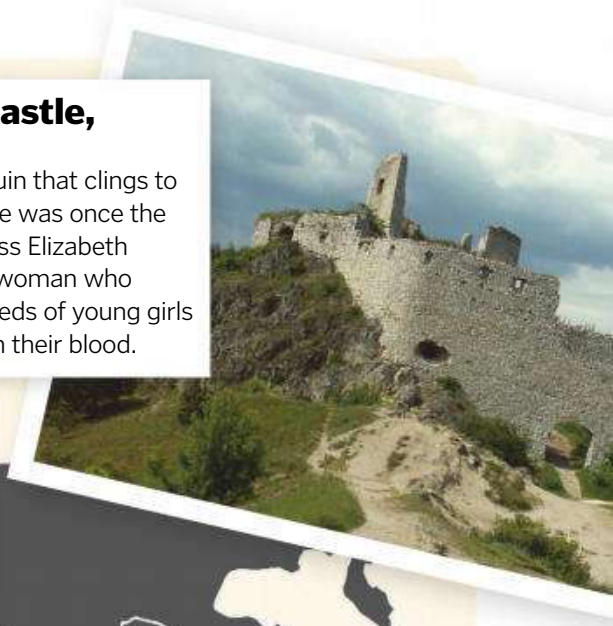

© Getty

Tower of London, England

Visitors have regularly witnessed the spirits of those who were executed on this site, along with spectral sightings of the exotic animals that were once kept here, prowling along the walls of the keep.

Cachtice Castle, Slovakia

The crumbling ruin that clings to the mountainside was once the home of Countess Elizabeth Báthory, an evil woman who murdered hundreds of young girls before bathing in their blood.




© Getty

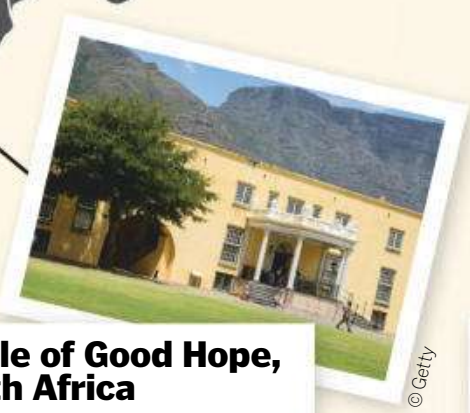
Borden House, Massachusetts

Visitors at Lizzie Borden's home have often claimed to see glowing orbs in the bedroom where Mr and Mrs Borden were murdered with a sharpened axe.


© Getty

Island of Dolls, Mexico

The ghost of a child who drowned in Lake Xochimilco is kept at bay by offerings of discarded dolls, which are hung from the surrounding trees.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Castle of Good Hope, South Africa

Thanks to the horrific executions that occurred within the walls of this fortress, hundreds of visitors have claimed to see screaming spectres and ghostly figures.


© Getty

Poveglia, Italy

This abandoned island was once a psychiatric hospital with an accompanying plague pit, but today the only inhabitants are apparently the tortured spirits that haunt its dilapidated ruins.

Debunked by the baffle room

As honorary director of the National Laboratory of Psychical Research, Harry Price, the famous British paranormal investigator, was instrumental in the development of a research centre designed to carry out a series of experiments concerning the supernatural.

The Laboratory was crammed with scientific equipment, including thermographs and barographs that measured changes in temperature and atmospheric pressure. A dark room was built alongside the lab so that photographic evidence could be developed on site without the fear of tampering from non-scientific parties, while a work room was used to invent new and exciting ways to investigate paranormal phenomena.

However, it was the 'baffle chamber', designed by Price himself, that ensured no fraudulent behaviour could occur. This clever room was placed between the laboratory and the séance room, with the intention of stopping any sound or light escaping during any so-called 'paranormal activity', such as ghostly knocking or floating orbs.


The interior of the National Laboratory for Psychical Research in 1930
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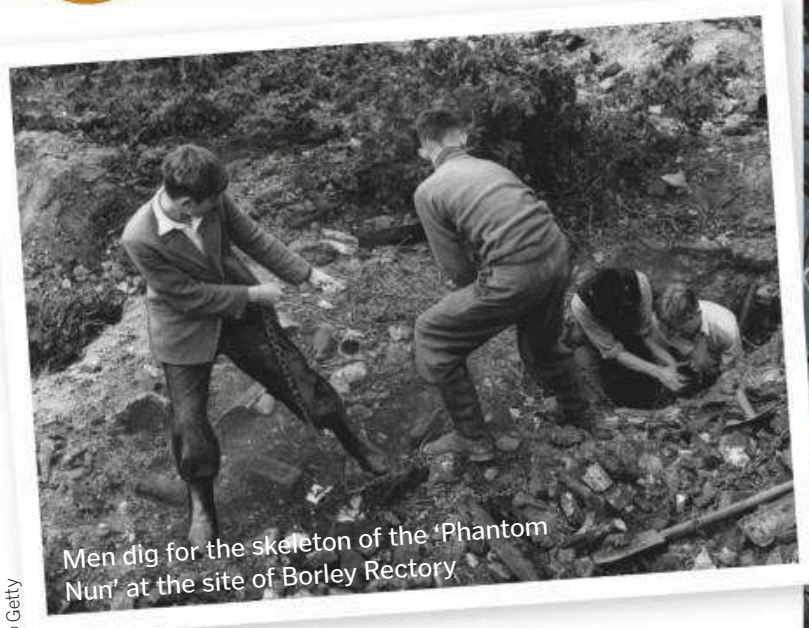


Men dig for the skeleton of the 'Phantom Nun' at the site of Borley Rectory

© Getty

steady stream of horror films from director James Wan and his 'Conjuring universe'. This series of inter-related movies covers the adventures of real-life ghost hunters Ed and Lorraine Warren, who investigated the purported hauntings of the 'Amityville Horror' house, the demonic possession of Arne Cheyenne Johnson, the Enfield haunting and the possession of the hideous Annabelle doll.

Modern-day ghost hunters use a wide variety of methods and equipment, from thermographic cameras, Geiger counters and ultrasonic motion sensors, to basic disposable cameras and dowsing rods in their quest to discover the truth. The most professional groups will always attempt to identify logical explanations for supposed supernatural occurrences before jumping to any paranormal conclusions. But rather than undermining the world of ghost hunting, this methodology allows us to truly wonder at the cases of paranormal activity that cannot be explained.

While Harry Price debunked many ghostly images, some pictures baffle investigators to this day, and every now and then a case of supernatural shenanigans occurs that no one can fully discredit. Could these events and photographs be the evidence that they are searching for, to prove the existence of ghosts?

The Enfield haunting

In 1977, one of the most famous accounts of poltergeist activity occurred in a council house in Enfield, England. Single mother Peggy Hodgson and her four children claimed to have been terrorised by unknown supernatural phenomena over a period of 18 months. This included two of her daughters levitating above their beds, flying toys and disembodied voices calling out in the night. Over 30 people, including police officers, neighbours and journalists all witnessed ghostly activities at the house.

Although some claimed it to be an elaborate hoax, many paranormal investigators are convinced of its authenticity and cannot explain the horrifying events that were recorded.

Supernatural phenomena?

There are logical explanations for most paranormal sounds and movements

Unwanted visitors

A door suddenly opening when no one is there could simply be due to a draft blowing down the chimney.

Waves of fear

Low-frequency soundwaves caused by thunder and lightning can be subconsciously acknowledged by the human ear and are known to cause feelings of terror.

Monstrous mildew

Toxic mould, often growing in abandoned houses, can cause neurological problems, such as sudden irrational fears and delirious visions.

Q&A Meet a real-life ghostbuster

While many fear an encounter with ghosts, Jenny Gibson actively hunts them down

What initially got you interested in ghost hunting?
I became interested in the paranormal world as a child, as I grew up in a house that had a lot of activity – doors closing, toys being thrown across rooms and bedsheets pulled during the night. Because I grew up in what I believed to be a haunted house, it sparked my interest as an adult in the supernatural.

What has been the scariest investigation you've undertaken?
It has to be what we call "the little church in the middle of the forest". It has a very intimidating feel, and we have had many unpleasant experiences in there.

You can feel the spirit – an old priest with a dark history. He comes up so close to your face, you can almost feel his breath. Sometimes he will make a growling sound. When he is present all of the ghost-hunting equipment will flash to show strong paranormal energy is around. The church is always freezing cold. We turn the torches out and sit in the dark just listening and waiting for his presence to arrive. We have experienced stones thrown at us, the main door into the church opened and slammed so hard it shook the walls.

Two investigations have had to be closed down early due to physical attacks, including scratching on an investigator's head and the feeling of pressure on another's neck. This is certainly not somewhere that I would take or advise anyone inexperienced to go, as I think it could potentially be a very dangerous place.

If you could investigate anywhere in the world, where would you go ghost hunting?
The Myrtles plantation, in New Orleans. I have heard many fascinating stories about the building, with murder victims still hanging around for many years following their death, including a small child who peers and waves out of the window at you... she has even been known to jump on the beds of visitors who are staying there.

A ghost hunter's bag of tricks

No ghost hunter should leave home without this handy paranormal toolkit

Digital voice recorder
Used to record witness interviews and capture any unexplained electronic voice phenomena. Use an external microphone for added clarity.

Torch
Don't go anywhere without a reliable, high-powered torch and plenty of spare batteries.

Remote sensor wireless thermometer
Use wireless technology to sense sudden temperature fluctuations and eerie cold spots.

Warm clothing
Haunted houses can be cold and damp. Don't forget your woolly jumper, waterproof boots and a blanket.

The Ovilus ghost box
This speech-synthesis device detects electromagnetic field changes and blends the information with a database of words, apparently allowing a spirit to communicate.

An electromagnetic field reader is demonstrated outside a florida ghost-hunting kit store

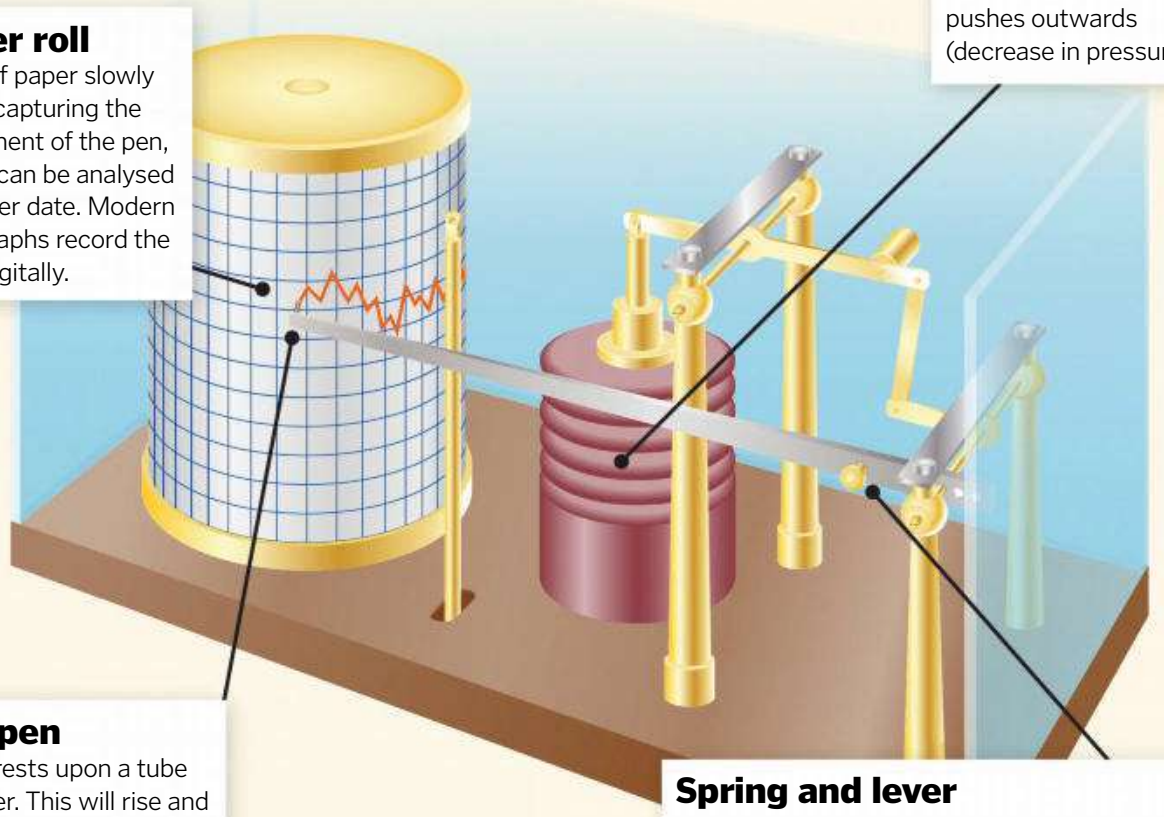
© Getty

Compass
A simple, inexpensive compass can alert the ghost hunter to electromagnetic field changes.

© David Cousens

Eerie atmospheric changes

A ghost hunter will use a barograph (like the old-fashioned one here) to record sudden changes in atmospheric pressure



Paper roll
A roll of paper slowly turns, capturing the movement of the pen, which can be analysed at a later date. Modern barographs record the data digitally.

Aneroid cylinder
As the air pressure changes, the cylinder either squeezes inwards (increase in pressure) or pushes outwards (decrease in pressure).

The pen
A pen rests upon a tube of paper. This will rise and fall with the changing atmospheric pressure.

Spring and lever
A spring picks up the movements of the cylinder, which in turn moves levers attached to a pen. Modern barographs use an LCD screen.

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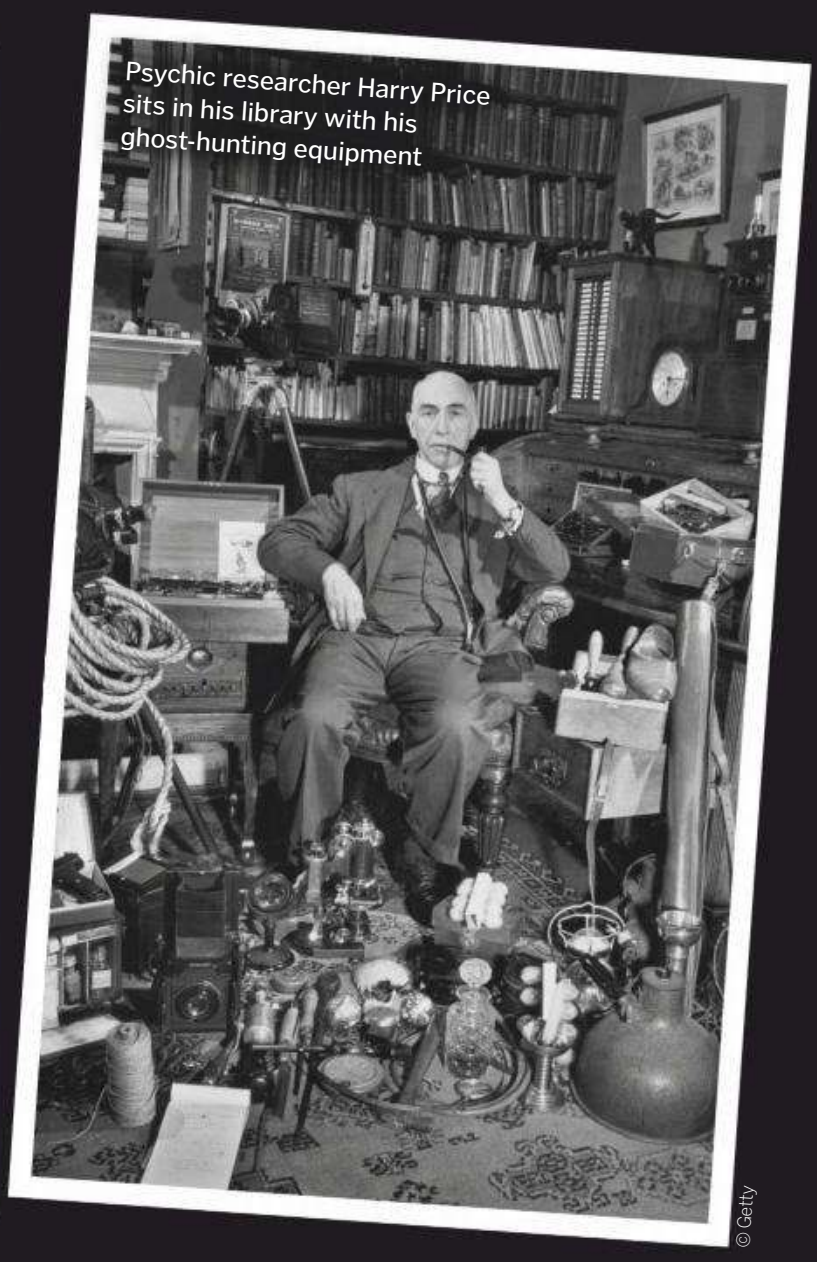

Psychic researcher Harry Price sits in his library with his ghost-hunting equipment

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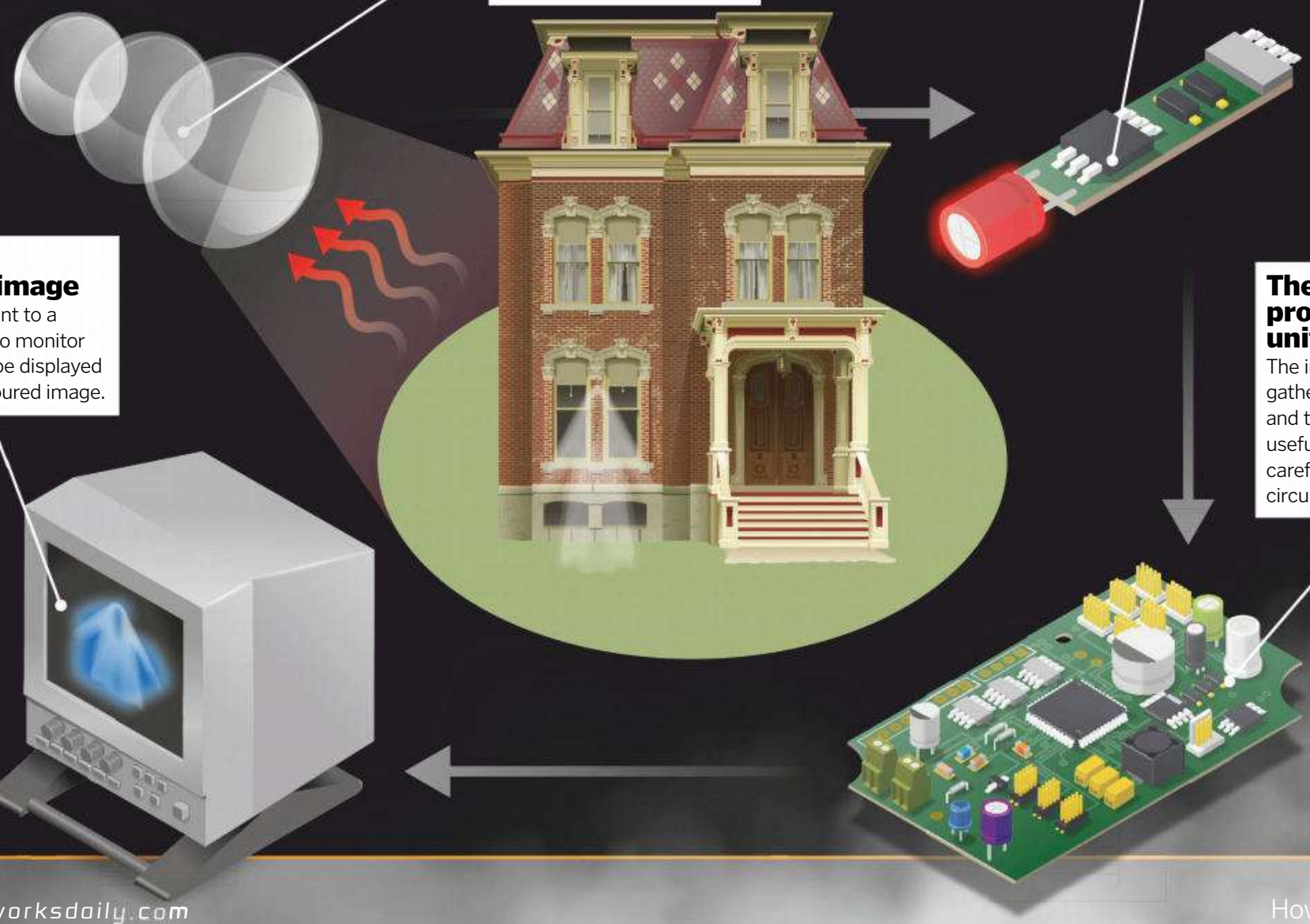
Seeing in the dark

Night-vision technology is vital for a ghost hunter who wants to track spooks in a pitch-black environment



Specialist lens
A specialised lens picks up and focuses upon the heat that all objects emit and sends the information to a series of infrared detectors.

Infrared detectors
The detectors create a detailed temperature pattern, or 'thermogram', which is transformed into a series of electric pulses.

The final thermal image
The data is sent to a standard video monitor where it can be displayed as a multicoloured image.

The signal processing unit
The information is gathered by the SPU and translated into useful data by a carefully developed circuit board.

© The Art Agency; Getty

SPIRIT IN THE PSYCHOLOGY

Parapsychologist Dr Ciarán O'Keeffe tells us how the mind can affect ghost encounters and a weird experience that even he can't explain


Dr O'Keeffe has written books and articles outlining the best ways to investigate the paranormal

With over 30 years of experience in the field of parapsychology, Dr O'Keeffe is a leading expert in investigating the paranormal. Now the Associate Head of School for Human & Social Sciences at Bucks New University, Dr O'Keeffe has authored several books on the topic of paranormal investigation and has appeared on TV's *Most Haunted*.

How would you define parapsychology?

Parapsychology is very broad, but the definition would be the scientific research into paranormal phenomena. The problem with that definition is it sounds like it encompasses all paranormal phenomena, so everything from the Loch Ness Monster to alien abduction and ghosts. This is not strictly the case.

Parapsychology is fundamentally interested in studying extrasensory perception (ESP), which covers three areas: telepathy, clairvoyance and precognition; psychokinesis, which is the action of the mind on an object – the classic example is Uri Geller and his spoon bending; and then the third area is after-death communication or survival after death.

This is my area of expertise, and in the world today I would estimate that there's around 100 or so actual parapsychologists qualified to doctorate level, and out of that number you've then got a smaller group, maybe about 10-20 per cent, specifically interested in after-death communication and hauntings.

How would you explain some of the common experiences people have during a ghost investigation, such as a drop in temperature or feeling the presence of a ghost?

When you think about ghost hunting or ghostly experiences, ghost hunting is a whole different kettle of fish to be honest. But actual, spontaneous ghostly experiences when you visit a location... there are a number of different experiences you can have. They are all sensory.

The most common one is the sense of presence. You walk into a room and you think there's somebody else there with you. The explanations for that could be psychological or environmental. The psychological explanation for that could be down to suggestion. This is an explanation that holds ground for many ghostly experiences. If you walk into a room and we're specifically told that the room is haunted or that the location is haunted, then suggestion kicks in. It's kind of a cultural norm for people to think if there is a ghost, they are either going to see it, which is so rare, or they're going to feel a presence in some way.

There's an interplay that happens between psychology and the environment, too. Imagine you walk into the same room and there is a temperature drop, which suddenly feels very, very calm. Now, that could be down to simple suggestion again, without anything happening, and the temperature remains consistent.

Being told a place is haunted can give you the experience of feeling as though the temperature is dropping. That can be down to the simple 'fight or flight' response. A fearful response to anything can affect your physiology in a particular way. The fearful action to the fact that there might be a ghost in the room is that you want to run. Then, of course, we know physiologically what happens is the blood is redirected into your legs and your body gets ready to run. By doing that, your physiology is changing. The upper part of the body is giving you the perception that your temperature is reduced.

> "Often it doesn't have to be accurate, it's down to people's belief system"

But it can be even simpler than that. You could walk into a room and feel a draft or a drop in temperature, and immediately associate that with a ghost because you've been told the room or the location is haunted. Imagine walking into an office and you felt the temperature go down, or a draft – you'd immediately be looking for the window or the air conditioning. You wouldn't be thinking there's a ghost. The drop in temperature could simply be a door or window that's open, but suggestion leads to a misinterpretation of environmental changes.

There are a couple of examples of people having the sense that they are being touched. That could be down to a number of different reasons, such as suggestion, but also electromagnetic fields. Electromagnetic fields can have observable physical effects, producing sound and problems with electronic kits, but it's actually both natural and man-made. Particular levels can produce the hallucination of a sense of presence, or a tactile sensation.

Infrasound too can play an exacerbating role. Particular levels of infrasound can cause an eye-oscillation effect. It can actually oscillate the eyeball to an extent where you get smearing in the corner of the eye. When you turn around to try and find out what that dark smearing is in your peripheral vision, you look and it's gone.

Why do you think people are so willing to accept these experiences as paranormal?

The most immediate explanation is hope – hope that there is something in the afterlife. If they are having a ghostly experience, then there's evidence of that. I have to say, while that might be the case for some people, I don't think it's the best explanation for why people have these experiences and believe it's a ghost. I think it's a combination of not being aware of natural explanations. The hairs going up on the back of your neck, for example, could be a number of different environmental and psychological reasons. If you've got no knowledge of that, a simple explanation would be ghosts. It's a lot easier to process what has happened to you with one simple answer, especially if you believe in that sort of thing.

There's another aspect to this. Across the country, there are hundreds if not thousands of people going out ghost hunting, it's an incredibly popular pastime. I question whether all of those people are interpreting their experiences as a

ghost presence in the hope of an afterlife, or actually if it's some sort of fairground pastime. It's an exciting, adrenaline-fueled experience – to be in a haunted castle or a haunted prison and think you could potentially have a ghost experience and could meet a ghost tonight.

What would you say are natural explanations for mediums who claim to have contacted spirits?

If you take a single scenario where a medium walks into a haunted location and starts to talk about a name, date and details associated with a person that is historically accurate, there's a number of different things going on. The medium may have fraudulently conducted previous research and regurgitated the facts as if it's coming to them paranormally.

The other explanation is they may not be aware that they've picked up on that information naturally, as opposed to through prior research. If the location is a National Trust property or English Heritage, for example, where there's information around the location, they may have processed that information but not be fully aware that they've done it. It's almost a form of cryptomnesia, where it's gone into their consciousness but they're not fully aware of it, and they have no memory of how they got the information, passing it off as being paranormal.

Another explanation, depending on their accuracy, could be the result of using simple psychological techniques that we know of that are used by pseudo-psychics. Almost like a detective exercise on the medium's part, they start to narrow down the information. Simple statements, such as "I'm getting a gentleman here in the corner, not sure if he's old" – it sounds like a statement but actually had a rising point at the end. It's encouraging anybody within that room who actually knows the information. Then they'll extrapolate more: "This is a father or grandfather and I'm getting a name, quite a simple name," looking at the reaction of people in the room and so on.

People are not concerned about the historical accuracy of it. I've been in investigations where mediums have gone, "I'm getting a very aggressive evil man here called Dave in the corner who used to work here as a cleaner, but then something bad happened with the owner of the location." And that's it, nothing historically accurate, and then suddenly you walk into another room and there's people sitting around a Ouija board trying to contact Dave. That's what I mean – often it doesn't have to be accurate, it's down to people's belief system.

Has there ever been a situation where you've thought, "Actually, I'm not quite sure how to explain that"?

There have been a couple of what I call head-scratching moments. There's an example in a nightclub in Birkenhead. The staff and owners of the nightclub reported that the fire exit doors would open of their own accord. Looking at the video footage and having investigated it, you could see that it appears there's no way you can push those doors open from the other side. We even had a chair wedged into the fire exit door so it couldn't open up on its own, but the doors tried to open to the extent that they almost pushed out the chair that was wedged.

At the same location, a group of staff members had been involved in a seance several years prior – a seance they felt kicked off all the phenomena that started in the nightclub, which I'm very sceptical of. But they happened to be at the nightclub the night of our investigation, spontaneously arriving after they heard we were there. Myself and the other investigator said, "While you're here, would you be interested in replicating that seance just so we can see where people were sat at the table, where the table was, etc.?" I thought that now we had a perfect opportunity to try and replicate circumstances after which this phenomena happened. We can't replicate the environment, such as humidity levels, air pressure and temperature, but still, in terms of the physical seating at least in a sense of what's going on [we could replicate it].

I was observing the seance using a thermal imager, which is a way of assessing relative temperature. I have it set to black and white because a drop in temperature goes green, so it's very easy and quick to see a change. After about 20-30 minutes the staff doing the seance said it didn't feel as though anything's happening. What I didn't tell them was that out of the corners of the room was like a green fog – the temperature was dropping and coming slowly into the room. Over time they began saying that the energy was very strong around them, and during a period of around 20-30 minutes this drop in temperature appeared to surround the seance table.

Then one of the ladies said it felt as though the energy was going away. As she said that it appeared as though the green fog, this drop in temperature, was actually just dissipating. It's just kind of going away from a central point in the room and then just dissipating out of the room. That's an odd thing to happen, a head-scratching moment.

The spooky experiences some people have in a seance are usually explained by simple human psychology

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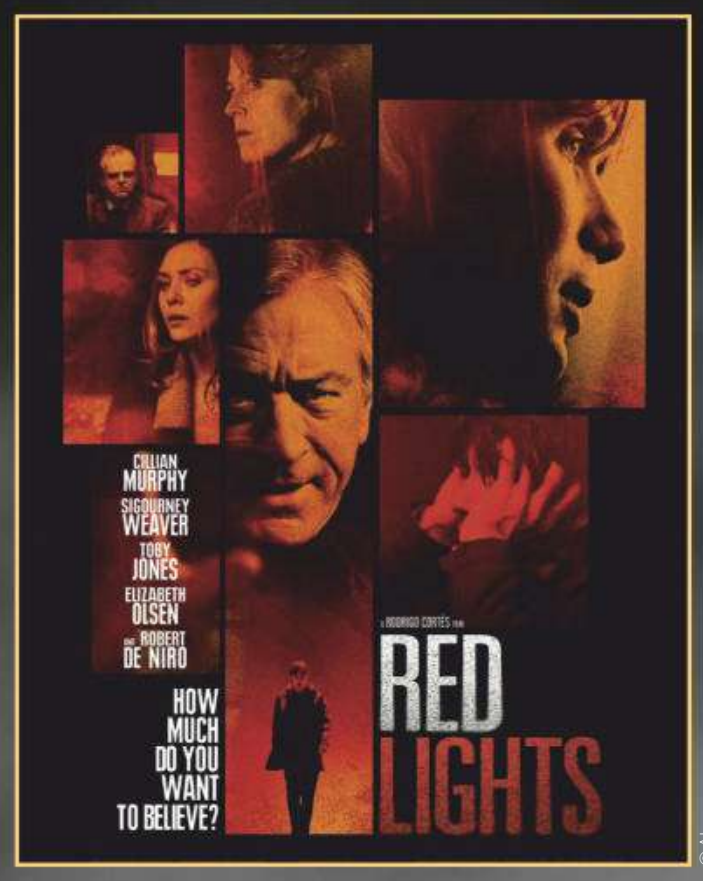
Dr O'Keeffe was involved in the consultancy and review of the 2012 paranormal movie *Red Lights*



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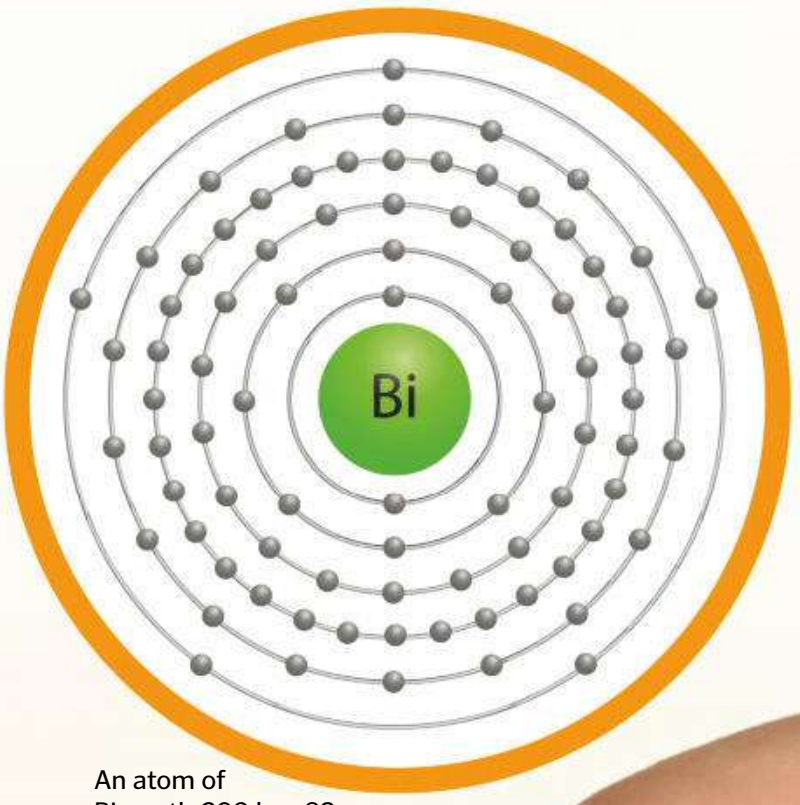
Bismuth: the pretty impatient metal

Its low melting point allows easy crystal formation – and can make spoons melt in hot tea

We know about bismuth's unusual beauty because it also melts unusually easily. This metal element turns from solid to liquid at 271 degrees Celsius. That's still more than enough to burn yourself, but much lower than other metals, which melt at thousands of degrees Celsius.

As it cools down, highly pure bismuth can form into stepped pyramids and other interesting and strange forms. This type of crystal is known as a 'hopper'.



An atom of Bismuth-209 has 83 protons and 126 neutrons in its nucleus, with 83 electrons in its shell

The hopper crystal forms because as it cools, bismuth is strongly driven to rapidly form hard edges in preparation for making a cube-shaped crystal. However, the strong driving force never lets the faces grow. Instead it impatiently forms more edges, leaving metal spirals that merge into unusual structures. The bare metal can then also quickly react with oxygen in the air, forming a shiny, coloured surface.

This low melting point can be useful – and was also used in practical jokes. Mixing bismuth with other metals lowers their melting points, making easy-to-shape alloys. Today dentists use such alloys to make moulds of people's mouths. Once people mixed bismuth with antimony (a metal-like element) to make type metal, which was used to print old books.

In the 1800s, Victorian pranksters made spoons from an alloy of eight parts bismuth, five parts lead and three parts tin. The alloy's melting point was low enough for the spoons to vanish into a cup of hot tea. Given that today we know that lead can be poisonous, hopefully the victims didn't finish their drinks!

This stepped pyramid of bismuth is called a 'hopper crystal'

How to make bismuth crystals

Thanks to its low melting point, you can in theory make pretty bismuth crystals at home. However, the temperatures and open flames involved still mean that great care is needed. Preferably, you should do it with an expert in a lab or a metalsmith's forge.

To form the beautiful crystals, first put high-purity bismuth in an iron or steel container, for example a clean steel can. Then, heat the container to bismuth's melting point, 271°C, using a gas flame, like a stove or a Bunsen burner, or an electrical hotplate. Turn off the heat, and when the bismuth freezes over, poke two holes in the solid surface. Pour the remaining liquid bismuth into a second iron or steel container, and leave to cool.

When it has cooled, break open the metal to find shiny, stepped bismuth crystals. And if you aren't satisfied, you can re-melt the bismuth and try again!

When bismuth metal reacts with oxygen, it forms a colourful, shiny outer covering

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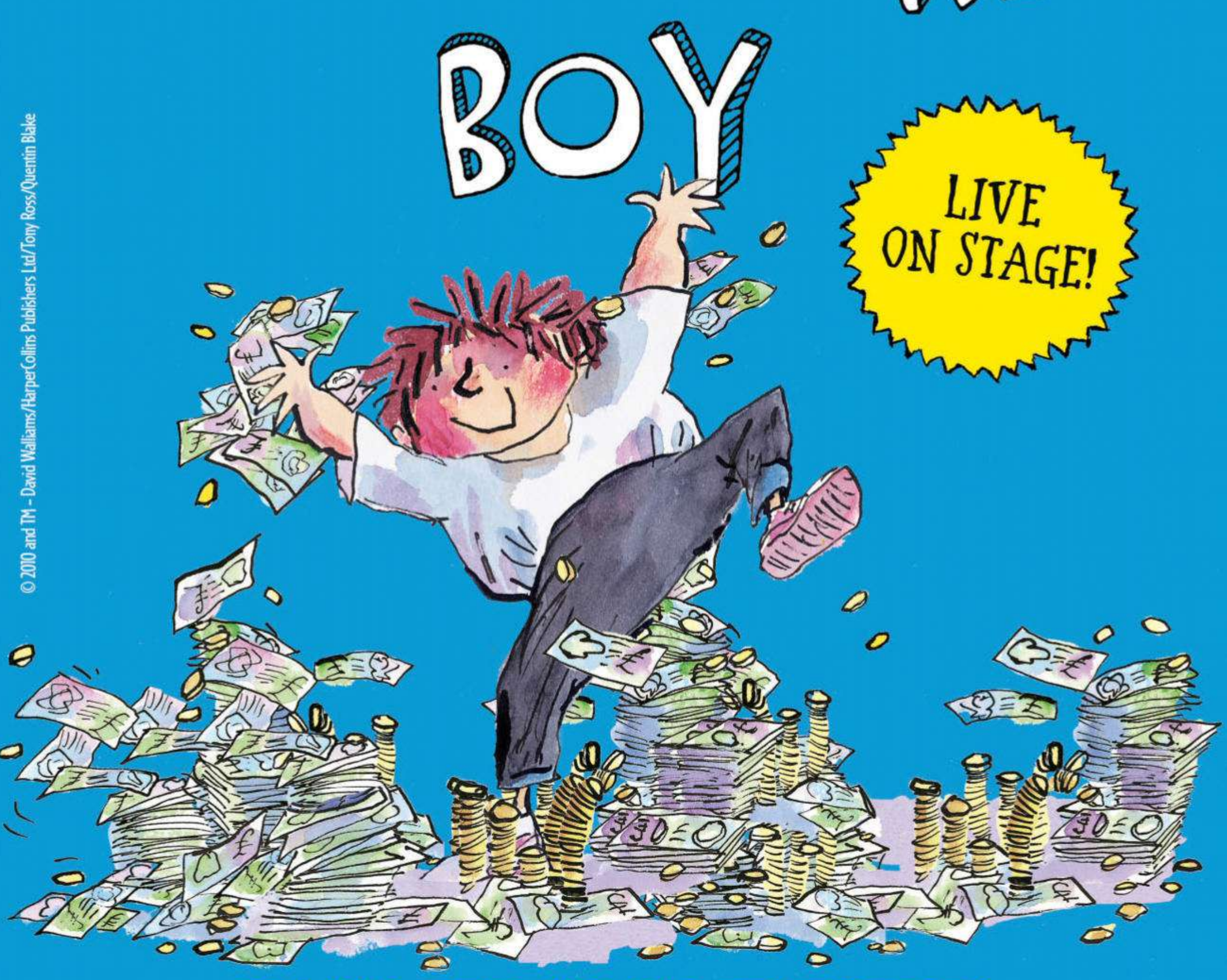

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HOW PLANETS ARE MADE

Discover how the dust and gas swirling around a newly formed star coalesces into a planetary system

Words by **Dr Andrew May**

NASA's Transiting Exoplanet Survey Satellite (TESS) searches for Earth-sized planets in systems near our Solar System

Planet formation is a spinoff – literally – of star formation. Stars are born in interstellar space, which for the most part is filled with extremely tenuous gas and dust. But some regions of the interstellar medium, called molecular clouds, are much denser than their surroundings. It's here that star formation takes place. The cloud's gravity is strong enough to make it collapse down in size, from several light years across to something like the present size of the Solar System. By contracting so much, the material in the cloud starts to spin more rapidly – as ice skaters do when they pull their arms in. While most of the mass in the cloud collapses down to the central star, the excess spin creates a wide disc of material orbiting the newly formed star. It's from this 'protoplanetary disc' that planets will form.

Although the basic mechanism of star formation has been known for a long time, our understanding of planet formation is much more recent. The conventional wisdom now is that the vast majority of stars are formed with planetary systems around them, but until the present century this was a highly speculative view. Very few 'exoplanets' – planets around other stars – were known, and no one had ever seen a protoplanetary disc. Since then, Kepler and other telescopes have discovered thousands

"Excess spin creates a wide disc of material orbiting the newly formed star"

New discoveries

For centuries, astronomers had just one planetary system – our own – to study. So they tailored their theories to what we see here: a few small, rocky inner planets, with gas-enshrouded giants further out. With the discovery of exoplanets, they now had a plethora of apparently 'impossible' worlds.

The first exoplanet around another Sun-like star – 51 Pegasi b – was a case in point. It looked like Jupiter, except that it was closer to its star than Mercury is to ours. Many other 'hot Jupiters' have been found since then, in places it should be impossible for large, gas-enveloped planets to form. It's more likely they formed much further out and drifted in to their present locations later on.

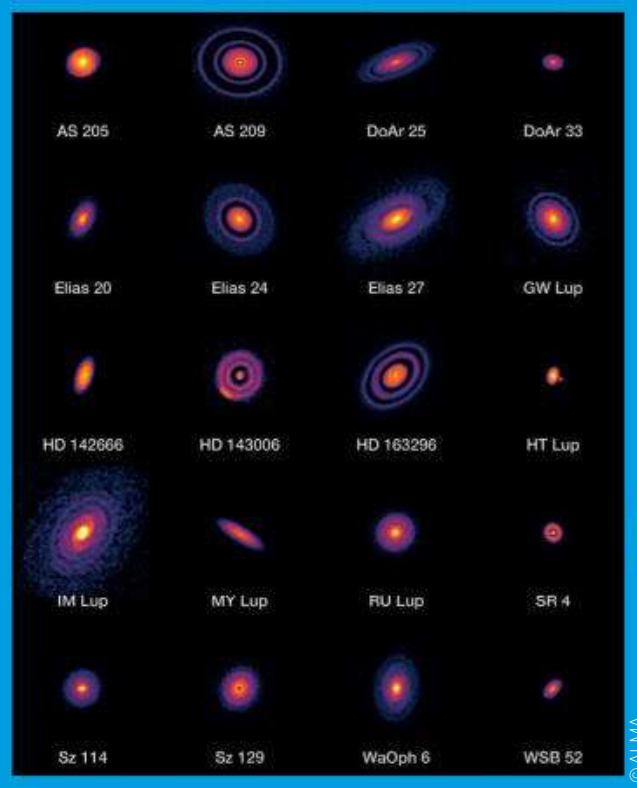
Other anomalies include 'super-Earths' – rocky worlds so large they could never have formed here in our Solar System. This suggests that some protoplanetary discs contain much more dust than ours did.

Exoplanet 51 Pegasi b is a 'hot Jupiter', orbiting very close to its parent star

How to observe baby planets

Because protoplanetary discs are large compared to the size of a star, it's possible for astronomers to observe them directly. The discs aren't hot enough to produce visible light, but they can be seen at the longer wavelengths associated with radio waves.

One telescope that specialises in looking for protoplanetary discs is the Atacama Large Millimeter/submillimeter Array – or ALMA – constructed 5,000 metres above sea level in the Chilean Andes. A sprawling array of radio dishes, ALMA became fully operational in 2013. It has succeeded in imaging dozens of protoplanetary discs, giving astronomers a unique new perspective on the processes involved in planet formation.



© ALMA

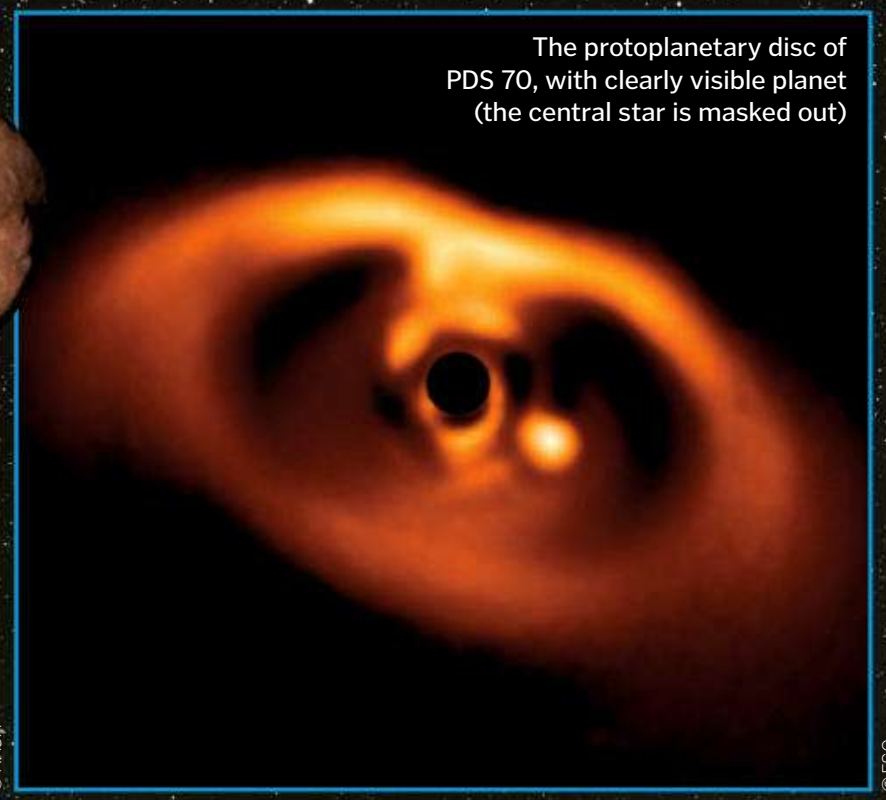
Real images – not artist impressions – of some of the protoplanetary discs seen by ALMA

An artist's impression of a dusty protoplanetary disc around a newly formed star

© ESO

Ultima Thule is a striking example of how planetesimals are built up by low-speed collisions

© NASA



The protoplanetary disc of PDS 70, with clearly visible planet (the central star is masked out)

© ESO

"What happens in a low-speed collision between two planetesimals? The result isn't a huge smash-up, but a gentle merger"

of exoplanetary systems, while the ALMA radio telescope has imaged dozens of protoplanetary discs. One such disc, around the star PDS 70, even has a clearly visible planet forming inside it. Observations such as these, taken together with sophisticated computer simulations, have given us a much clearer picture of just how planets form.

The 'dust' in the protoplanetary disc starts out as microscopically small, solid particles. Close to the central star, these are mainly rocky or metallic in composition, switching to frozen hydrogen compounds – such as water ice, methane or ammonia – at larger distances. In both the 'rocky' and 'icy' regimes, events unfold in a similar way. As the dust particles travel around the star, all in slightly different orbits, they repeatedly collide with each other. These are relatively slow collisions, and the particles end up sticking to each other. This process – known as accretion – continues up the size scale until the particles become sizeable rocks, or 'planetesimals'.

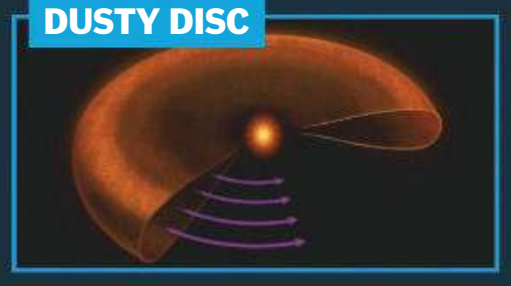
What happens in a low-speed collision between two planetesimals? The result isn't a huge smash-up, but a gentle merger of the two objects – as you can see by looking at Ultima Thule, the snowman-shaped object that NASA's New Horizons spacecraft photographed in January 2019. It's just another step in the planet-building process. In the case of Ultima Thule, which is on the fringes of the Solar System, there wasn't enough additional material to make a planet – but it's a very different case in the crowded inner parts of the protoplanetary disc. Here, an object can accrete enough mass for gravity to pull it into a roughly spherical shape, at which point it really starts to look like a planet.

There's another thing that needs explaining. The largest planets – like Jupiter and Saturn – have dense cores surrounded by huge envelopes of gas. How were they formed? The most probable scenario is that the cores were created by accretion, like a rocky planet, and their gravity then pulled in the envelope of gas. Alternatively, gravitational instabilities in the protoplanetary disc may have caused the gas to clump first, and it was the gravity of these clumps that pulled in dust and ice to form the planet's core.

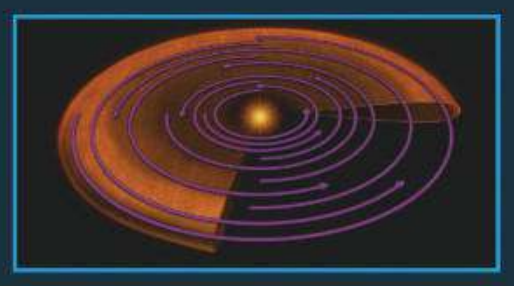
The two giant planet theories

Do Jupiter-like planets form core-first or gas-first? Either scenario is possible

DUSTY DISC



A dusty cloud orbits a newly formed star
Dust grains around a star slowly collide and then stick together, forming increasingly large planetesimals.



Planetary ‘seeds’ begin to stick together
The system gradually coalesces into protoplanets – inner rocky ones and outer icy ones.

Giant plants start to appear
The most massive protoplanets pull in gas molecules via gravity, forming large envelopes around them.

A mature planetary system
A mature system is a mix of smaller rocky planets and large, gas-enshrouded ones, like the Solar System we see today.

GASSY DISC

A huge cloud of gas surrounds the new star
This scenario envisages a higher proportion of gas in the disc, dense enough to have its own gravity.

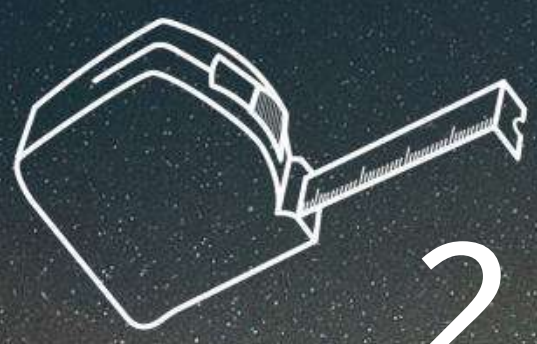
Clumps appear in the gas
Gravitational instabilities produce clumps in the gas – embryos of giant planets, forming this time from the ‘outside in’.

Giant planets form solid cores
The newly formed giant planets pull dust and ice into their cores, in a mirror image of the accretion scenario.

A similar outcome to the dusty disc?
Although the gas giants formed in a different way, the end result looks much the same in both scenarios.

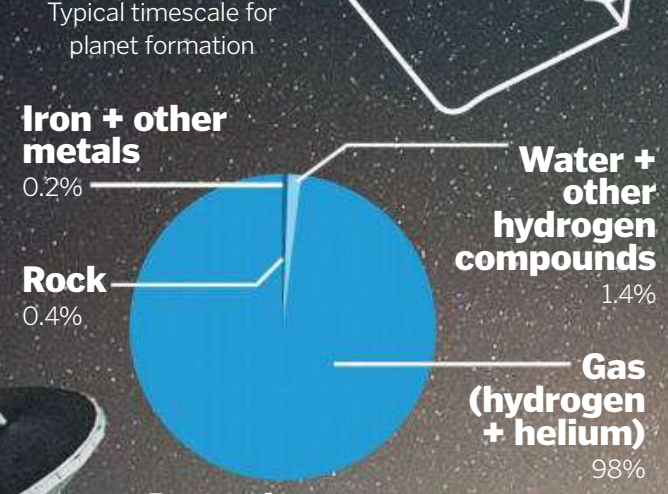
10
million years
Typical timescale for planet formation

100x
Diameter of a protoplanetary disc, compared to diameter of Earth’s orbit



50:50
Ratio of rocky planets to giant planets in Solar System

3,063
Number of known planetary systems



2,000°C
Earth’s surface temperature immediately after formation

99.6%
The giant planets make up most of the Solar System’s planetary mass

66
Number of radio dishes that make up the ALMA telescope

The first planet orbiting another Sun-like star was discovered in 1995

AR ZONE!

The Mars life-hunting rover

The European Space Agency's new explorer is our best hope yet of finding life on Mars

Earth is the only planet we know of that supports life – but was there ever life on Mars? Is there life on the Red Planet now that we simply haven't discovered yet?

Attempting to find answers to these questions, the European Space Agency (ESA) is prepping a rover mission. ExoMars is scheduled to launch in July 2020, with the rover due to land on Mars roughly eight months later.

Recently named Rosalind Franklin, this Martian explorer has been worked on for over a decade, so it is important that the landing goes smoothly. Preparing a robot for safe transport across millions of kilometres, to then land on a planet that's so different from our own, is far easier said than done. Engineers have designed a heat shield to protect the rover from the extreme rise in temperature generated when the spacecraft enters Mars's atmosphere, as well as parachutes and thrusters to control the landing.

Following successful contact with Mars, the discovery work can begin. Equipped with the tools to drill out and examine samples of the planet's surface, the rover will be the first of its kind from the ESA to safely navigate the planet and carry out in-depth analysis of its surface.

Within the samples taken, the rover is looking for preserved organic material. Because surface-level rock, dust and other materials are subjected to cosmic and solar radiation, the drill will extract soil from a range of depths. Any findings will be communicated back to Earth in radio waves via satellites, and at some point in the future these small samples of Mars could be taken back to Earth.

How will the rover work?

The rover, which is in its final stages of testing, will use a unique 'walking' technique to move and collect data

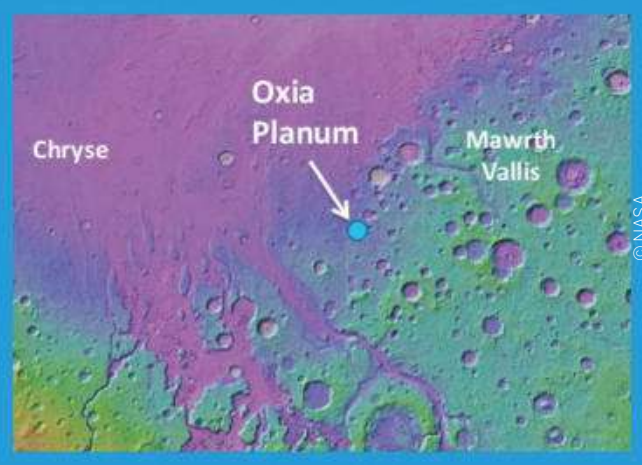
Where it will land

At what spot on Mars's 144 million square kilometres of dusty, rocky surface do you begin to analyse the planet?

In 2018, the preferred landing site was chosen. Known as Oxia Planum, the location is slightly north of the planet's equator. In order to discover whether there was ever life on Mars, the rover will land where scientists think there was once an 'ancient ocean'. Studies have shown that in Mars's early history, the planet was warmer and held water.

If the landing site was, in fact, once a large mass of water, then it is the best place to start searching for clues. Features that scientists are looking for in particular include clay rocks, which may have formed on the lake's floor almost 4 billion years ago. Scientists hope that analysis of these rocks could exhibit signs of any early lifeforms that existed on Mars.

Compared to other areas that hold scientific interest, Oxia Planum appears to have safer terrain to allow the successful landing and operation of the rover.



© NASA

Oxia Planum has few topographic obstacles, making it a safer landing site

26 kilograms
The mass of the scientific payload

70 metres
The distance Rosalind Franklin can travel per day

-120 degrees Celsius
The rover will endure extremely low temperatures on Mars

2cm per second
The maximum speed of the rover

AR ZONE! SCAN HERE

Localisation cameras
These cameras show an image of where the rover is in order to determine its movements.

Flexible wheels
Its six wheels can move independently in different directions. Using a method called 'wheel walking' they will almost move like legs to avoid sinking into sand.

Rover technicians wear protective clothing as part of strict rules preventing contamination

© Getty

"The rover will land where scientists think there was once an 'ancient ocean'"

© Adrian Mann

PanCam wide-angle cameras
This panoramic camera will supply 3D and stereo imagery of terrain. High up, it can show the ground around the rover.

Deployable mast
Providing height for the cameras to sit on, the mast increases the surface area covered by the rover's eyes.

WISDOM antennas (at the back)
The 'Water Ice and Subsurface Deposit Observation on Mars' step-frequency radar can display detailed 3D imaging of the surface structure, revealing up to three metres into Mars's upper crust.

1/100th
Mars has a tiny fraction of Earth's atmospheric pressure

Deployable solar arrays
The rover is entirely solar powered. This power is stored in a rechargeable battery for periods with no sunlight.

UHF antennas
These antennas receives and sends out information in all directions, by transmitting ultra-high-frequency radio waves.

Suspension assembly
The suspension system has been added to make it easier to drive on rough terrain.

Drill system
The drill unit will take soil samples two metres below ground level. It is designed to work in the varied soil types.

17
The minimum number of soil samples needed for analysis

Naming rover Rosalind Franklin

While previously known by its project name ExoMars, in February 2019 the rover was given the name 'Rosalind Franklin'. This name came from a pool of 36,000 public suggestions, from which a judging panel had the difficult task of selecting just one.

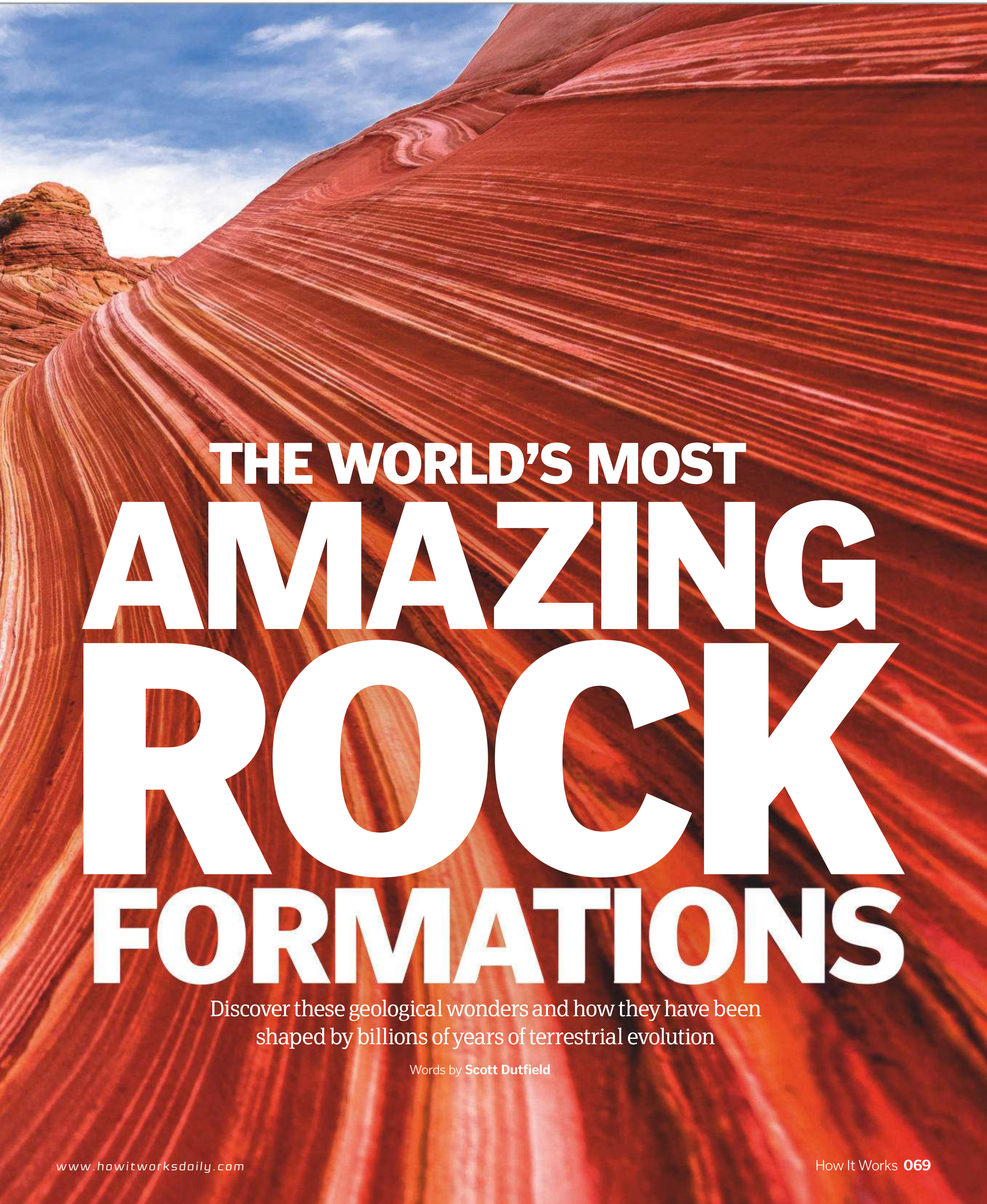
It is not immediately obvious why this rover has a human name, specifically that of the British chemist who contributed to the discovery of the structure of DNA. When Franklin made her DNA discovery in 1951, she used a process called x-ray diffraction analysis that revealed the helical structure of the molecule. It was her image, known as Photograph 51, that Watson and Crick used to publish their findings for the structure of DNA.

So what is the relationship between DNA and Mars? The rationale behind the rover's naming stems from the main objective of the ExoMars mission – to search for life. While Franklin contributed to the discovery of the structure of our bodies' building blocks on Earth, hopefully her rover namesake can discover the building blocks for life on another planet.

© Getty

DNA pioneer Rosalind Franklin is one of science's most influential women

DID YOU KNOW? *Over the last 12,300 years, Niagara Falls has been eroded by around 11.4 kilometres*



THE WORLD'S MOST AMAZING ROCK FORMATIONS

Discover these geological wonders and how they have been shaped by billions of years of terrestrial evolution

Words by **Scott Dutfield**

© Getty

Devils Tower

Wyoming, USA

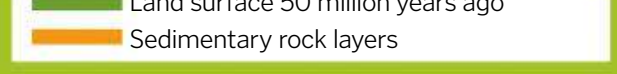
Towering above the trees of the Black Hills National Forest, this colossal monument appears to have sprouted straight from the underworld. The imposing geological formation is, in fact, the world's largest example of columnar jointing. From base to summit, Devils Tower reaches 264 metres high and is comprised of many three-metre-wide hexagonal columns.

Born from the flames of the Earth's core, geologists agree that this monument burst through our planet's crust as magma and cooled close to the surface. It is this cooling process that gives the rocks their unique geometry. As the igneous rock cools down it begins to contract around stress points, and over time the pressure builds around these points. As a result tessellating cracks form distinctive hexagonal shapes that release the pressure, running from the top to the bottom and forming the structure's multi-column architecture.

Although geologists have agreed on how columnar jointing forms, the unusual grandeur of Devils Tower has still got them scratching their heads.

Deciphering Devils Tower

Some of the theories to explain its origins



Stock theory

In the late 1800s geologists Carpenter and Russell suggested that Devils Tower formed as an igneous intrusion, forcing its way through the crust and into sedimentary rock on the surface. This is called a stock. The surrounding layers then eroded away, leaving behind the tower.

Laccolith theory

Scientists Darton and O'Hara offered a similar explanation in 1907, suggesting the columnar jointing formed as a mushroom-shaped laccolith. A laccolith forms in the same way as a stock, but the larval plume is more of a rounded bulge than an angular block.

Volcanic plug theory

Although there is limited evidence of volcanic activity at the site, some geologists believe that the hexagonal rocks formed beneath a prehistoric volcano. Without evidence of volcanic ash or debris it's hard to confirm, and any evidence could have eroded away.

Maar-diatreme theory

A maar-diatreme volcano isn't a fire-breathing variety, but rather explodes from super-heated groundwater. As the steam builds, the pressure can blow the top off the encapsulating rock, leaving a crater. Lava can fill the space and cool into a large chunk of columnar jointing.

The crystal cavern

In Mexico's Sierra de Naica mountain, there's a cave decorated with crystals that dwarf a car. Buried 300 metres beneath the surface, it wasn't until the cave was drained by miners that geologists discovered a treasure trove. It's known as the Cave of Crystals, where huge gypsum crystals slice through the cavernous space.

They exist due to groundwater that filled the cave. Laced with a mineral called anhydrite, the subterranean water source experienced slight changes in temperature due to magma. During temperature drops, this mineral solidified as gypsum.

© Science Photo Library

Just one of the cave's giant gypsum crystals weighs in at around 55 tons

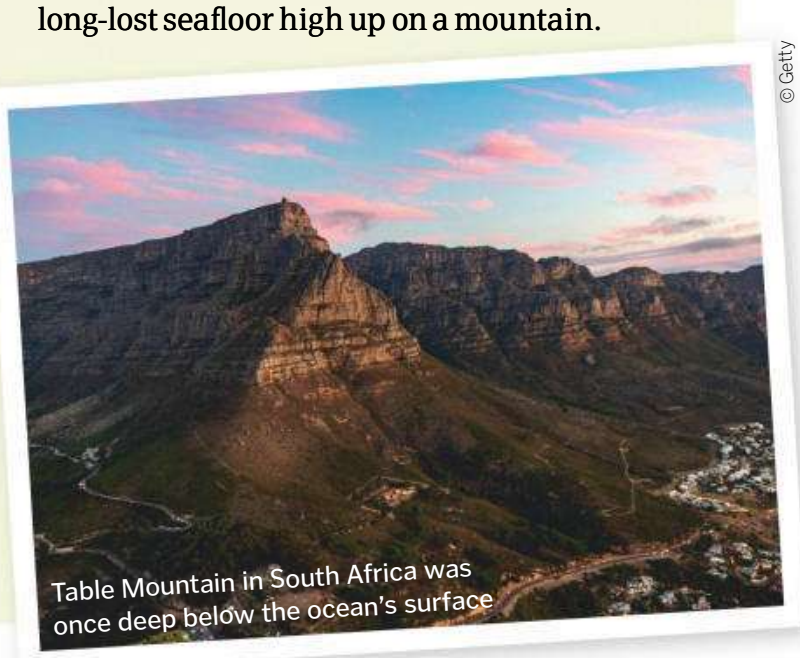
Table Mountain

Cape Town, South Africa

Mountains aren't all tall, rocky spikes on the Earth's surface, and Table Mountain is a notable example of this. Appearing as though mother nature has taken an eraser to the top of the mountains and made a clean line, Table Mountain is an unusual and dramatic sight.

Overlooking the city of Cape Town, this flattened peak is much more than a geological oddity but an example of how rocks can give us a glimpse back in time. Rocks, rubble and mountains are great indicators of prehistoric environments. Much like the way the rings in a cross-section of a tree's trunk reveals its age, different layers that make up a mountain's strata sheds light on changes to its environment over time.

Now towering at a height of 1,086 metres, the mountain was once submerged and part of the seafloor. During its time beneath the waves, it gradually collected sand and silt, which over millions of years compacted to form the dense sedimentary rock at the top the mountain. Beneath is sandstone topper, a strong igneous granite rock from a solidified magma plume. As the surrounding sea receded and the neighbouring rock was worn away, what now remains are the remnants of a long-lost seafloor high up on a mountain.



© Getty

Table Mountain in South Africa was once deep below the ocean's surface

Rocky forests Utah, USA

In the western US state of Utah, Bryce Canyon National Park is a red wonderland filled with rocky forests. Spanning as far as the eye can see, towering spires of undulating rock appear to have sprung from the ground below.

Like many of the other awe-inspiring formations in this feature, these unusual peaks are the result of millions of years of erosion. Once a giant plateau (a flat plain high above the ground), over time the elements have chipped away at it, slowly dissolving its landscape into these rocky statues, known as hoodoos.

This forest of stone has come to exist because of the irregular rate of the plateau's erosion. Made up of different layers of rock, plateaus form over millions of years, as sediment and rock piles up as a result of deposition or volcanic eruption. Each has different properties: some rocks, such as mudstone, react more quickly to erosion, while other layers of more dense rock, such as limestone, erode more slowly. This irregularity of erosion rates is known as 'differential erosion' and results in the formation of the hoodoo's spires.

"These unusual peaks are the result of millions of years of erosion"

Spanning 145 square kilometres, Bryce Canyon National Park is filled with unusual geological structures

© Getty

'Hoodoo' you think you are?

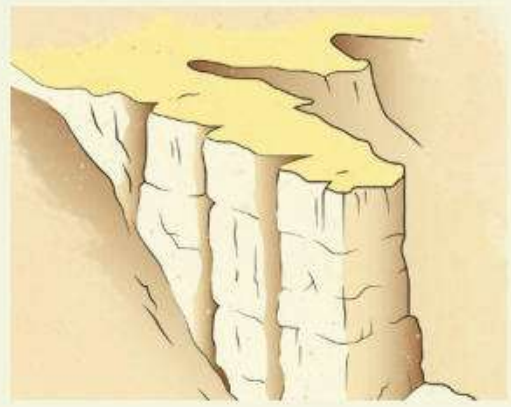
How these rocky outcrops got their unusual shape

Landscape

Bryce Canyon formed between 10-15 million years ago. The plateau is made up of several layers of different rocks, such as mudstone, limestone and dolomite.

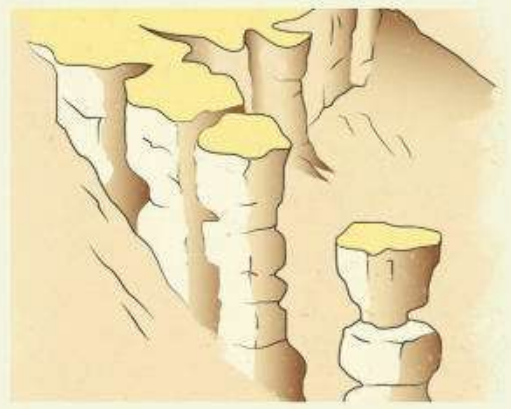
Wind and rain

Wind and rain gradually erode the plateau's softer mudstone at the lower sections. However, the upper dolomite and limestone layers are more resistant to erosion.



Deep freeze

As it's eroded, cracks form in the plateau's surface, allowing water to infiltrate into the rock. As the temperature falls this water freezes, expands and widens the cracks.



Hoodoo

Over millions of years, this cycle of continued erosion has carved the Bryce Canyon landscape into the forest of hoodoos we see today.

Antelope Canyon

Arizona, USA

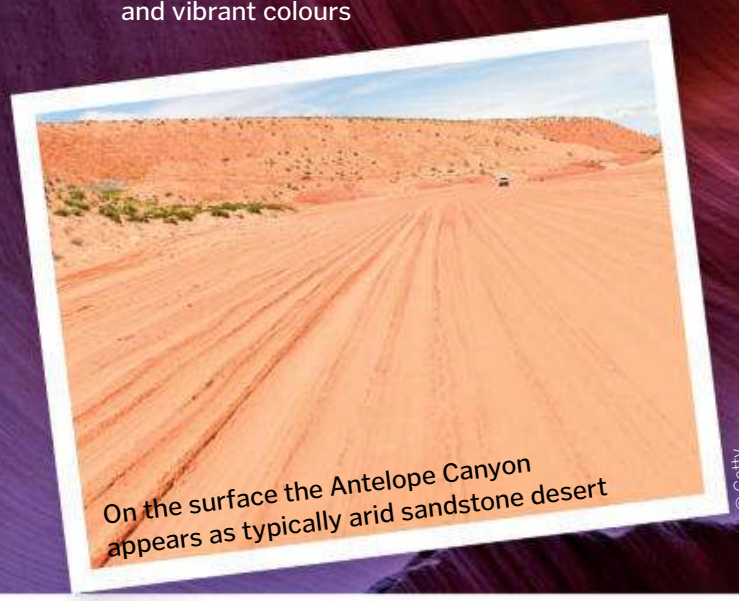
On the surface Antelope Canyon might not seem that impressive. However, deep between the cavernous cracks of this sandstone landscape is an intricate network of pathways boasting beautiful colours.

Because of its sedimentary composition, sandstone is highly susceptible to erosion and is easily carved into structures and shapes. Antelope Canyon is no exception. It's around 37 metres below the surface, and over millennia flash floods and strong winds carrying loose sediment have worn away at the sandstone to form what is referred to as a slot canyon.

Known for is the ability to transport visitors to a sandy subterranean world, Antelope Canyon is also flooded with an array of vibrant colours. Sandstone naturally appears red due to its high iron content. However, at the Antelope Canyon, the shape of slots allow the incoming light to bounce off its quartz-filled walls at different angles. This creates tonal changes in the colours that are reflected between each canyon crack. Vibrant reds at the entrance of a crack can descend into a spectrum of oranges, yellows, pinks and purples by the time the light reaches the floor of the canyon.

© Getty

Deep below the slot canyon it is a mystifying world of undulating pathways and vibrant colours



On the surface the Antelope Canyon appears as typically arid sandstone desert

© Getty

Wave Rock

Hyden, Australia

Australia is well known as one of the word's prime locations to surf the perfect wave. And near the town of Hyden is a wave 110 metres long. There's only one problem: it's made of solid rock.

Towering 15 metres into the air, this granite cliff, called Wave Rock, formed over 2,500 million years ago. As one side of an inselberg (an isolated hill or mountain rising from a plain), this concave cliff is known as a 'flared slope'.

Created by wind and rain erosion, it is comprised of coarse-grained porphyritic granite and igneous rock embedded with different minerals and crystals. As wind and rain has battered the wall, softer rock at the base has been undercut, producing its wave-like appearance.

Rainfall has not only helped to create the rock formation's shape but has also decorated it with a series of red, brown and yellow stripes. Although they might seem hand-painted, each vertical stripe is an indication of different mineral deposits washed down the slope, reacting with the water and producing different colours.

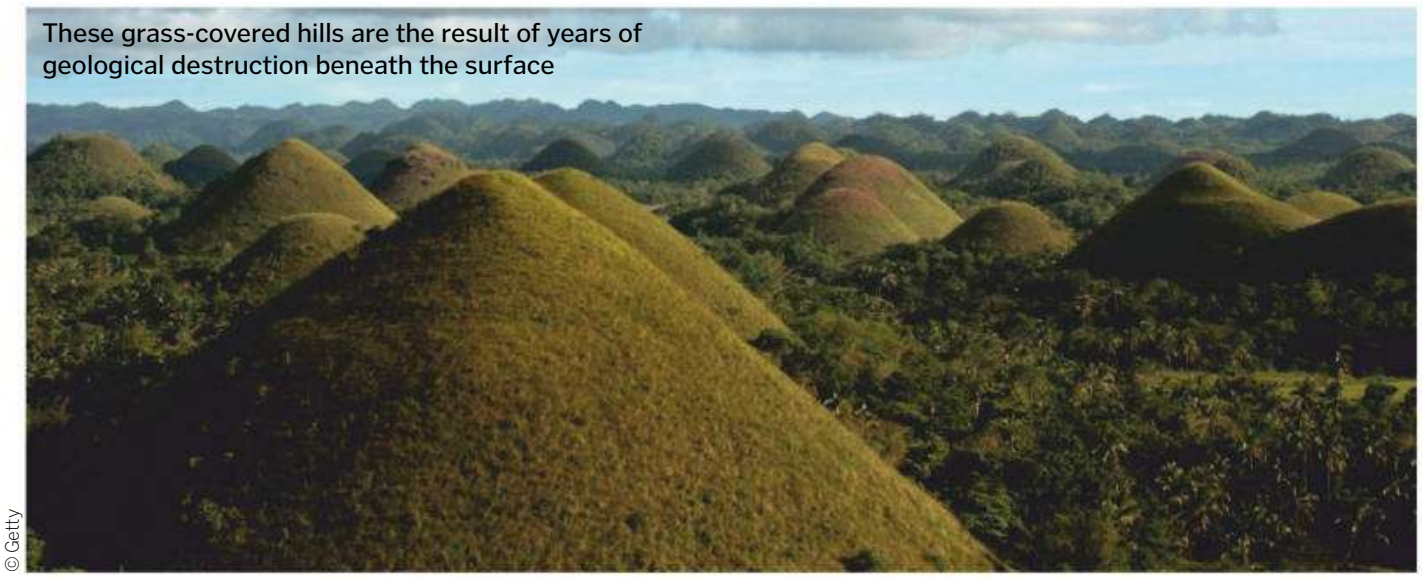
Water-loving algae also play a role in the cliff's colourisation. Usually staining the rock black, these tiny organisms develop a brownish colour during the dry seasons.

Wave Rock overlooks the picturesque farmlands of Western Australia

© Getty

Appearing to be a stone wave, this flared slope has been shaped by strong winds and rainfall

© Getty



These grass-covered hills are the result of years of geological destruction beneath the surface

Chocolate Hills

Bohol province, Philippines

Many mountains and hills form by rising out of the ground over millions of years, but the Chocolate Hills appeared after the world melted away around them. Mountains typically form from solidified magma that has been forced to the surface or as the result of two continents crashing into one another. But in some cases, mountains and other geological formations touch the skies in what are known as karsts.

Karsts are an area of land where the rocky foundations, typically limestone, have been eroded by heavy rainfall and groundwater. Formed from ancient compacted marine organic matter (such as tiny fossilised crustaceans), calcium-rich limestone is an easily dissolvable material. Continued erosion by water slowly creates caves and sinkholes, which causes the limestone at the surface to collapse. In turn, the surface topography changes, revealing mounds where patches of land haven't sunk.

There are many examples of karsts across the globe, some hosting more dramatic and irregular hills hundreds of metres tall. What makes the Chocolate Hills so unique is their repetition and smooth appearance. Around 1,260 to 1,776 of these almost dome-shaped hills are spread across the region, ranging in height from 30 to 120 metres tall.

The stone tree

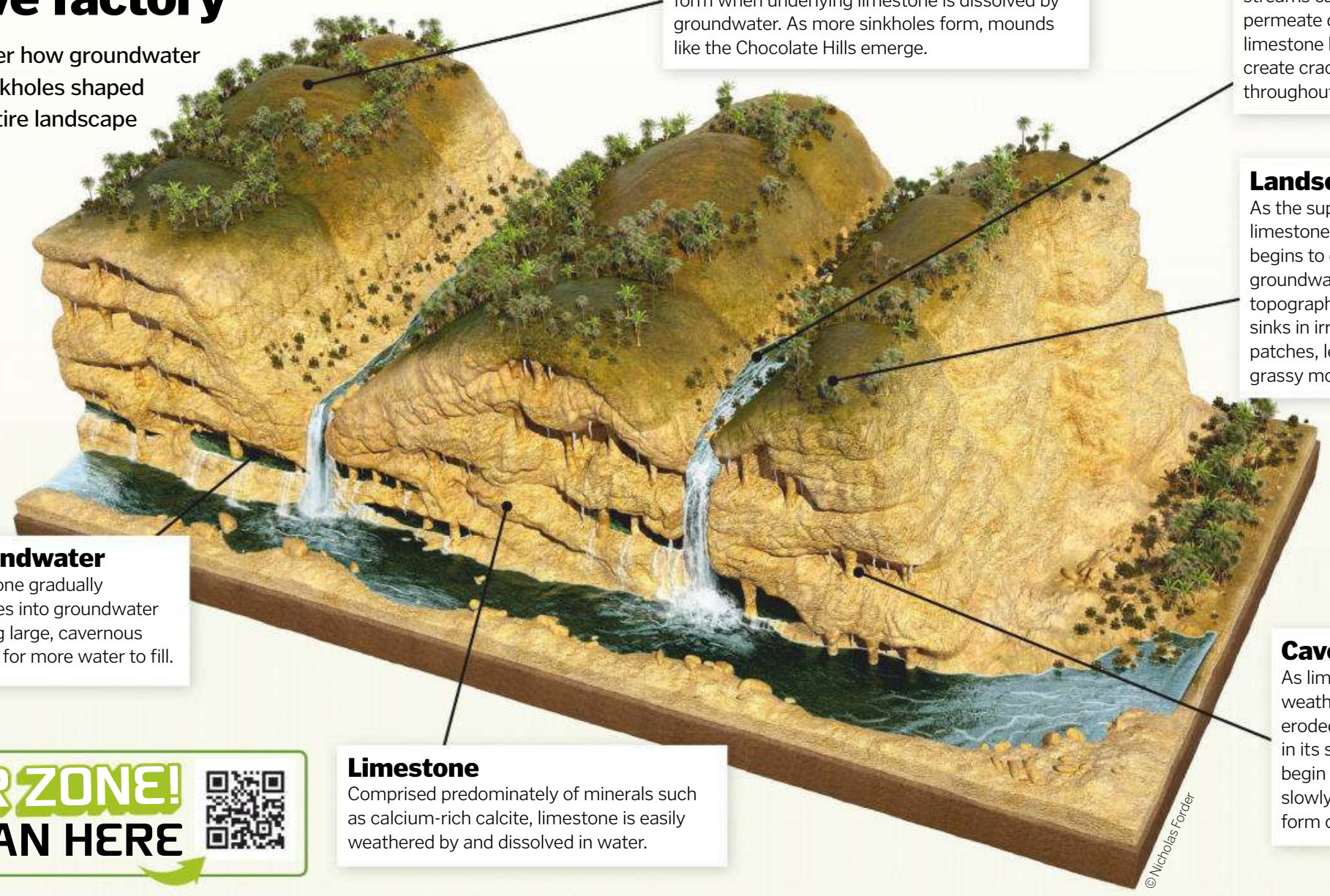
Standing alone in the arid expanse of the Siloli Desert in southwest Bolivia, one rocky formation is mimicking trees and puzzling spectators. Known as Árbol de Piedra or Stone Tree, this gravity-defying display is the result of violent volcanic activity millions of years ago.

This five-metre-tall chunk of volcanic rock is predominantly composed of two substances that have eroded over time to form its tree-like appearance. Giving the Stone Tree its 'trunk' and 'roots' is quartz, a mineral sensitive to erosion by wind. Desert winds are particularly eroding as they carry with them abrasive sand and salt. However, this 'tree' has been allowed to blossom thanks to its iron-rich mineral content, which is more resistant to weathering than quartz.

Appearing to defy gravity, the Stone Tree has strong geological roots that keep it upright

The chocolate cave factory

Discover how groundwater and sinkholes shaped this entire landscape



Hills from sinkholes
Depressions in the topography, called 'sinkholes', form when underlying limestone is dissolved by groundwater. As more sinkholes form, mounds like the Chocolate Hills emerge.

Rivers
Above-ground rivers and streams can, over time, permeate down into the limestone bedrock and create cracks throughout its structure.

Landscape
As the supporting limestone bedrock begins to dissolve in groundwater, the topography above sinks in irregular patches, leaving behind grassy mounds.

Groundwater
Limestone gradually collapses into groundwater creating large, cavernous regions for more water to fill.

Limestone
Comprised predominately of minerals such as calcium-rich calcite, limestone is easily weathered by and dissolved in water.

Caves
As limestone is weathered and eroded away, gaps in its structure begin to form and slowly hollow out to form caves.

AR ZONE! SCAN HERE

How do birds fly?

Their specialised frame is built for flight, from their bone structure to the way they breathe

If there's one thing humans tend to envy about other members of the animal kingdom, it's flight. Our natural capabilities limit us to only land and water, but for birds the sky is literally the limit. How is it that they can lift into the air with seemingly effortless movements?

Almost every part of a bird's body has evolved to maximise flying potential in some way. Relative to their size, birds' hearts are bigger and more powerful than those of most mammals, to keep essential flight muscles working. Birds also have huge breast bones, providing more space for flight muscle attachment.

Hollow bones enable oxygen to travel more freely around the body but still have the strength to tackle the strains of flight. Some birds have a skeleton that's even lighter than their feathers.

Birds' feathers, made from keratin, evolved from those of dinosaurs to provide a light surface that can push against the air to facilitate flight.

There are around 10,000 bird species, ranging in size from seven centimetres to over 1.8 metres, so the flying method and build of these birds can vary massively. Often, birds with smaller wings can hover by beating them at a rate of more than 40 times per second. Large wingspans enable low gliding, so birds exert no flapping energy at all.

However, studies have shown that small birds also glide through the air for breaks between flapping. A small bird's heart rate when gliding is half of what it is when it's flapping its wings. It was discovered that these birds require a similar amount of energy to glide as they do to rest in their nests. In comparison, when large birds soar above the wind, their energy expenditure was at least 30 per cent higher than when they were at rest.


4,000 bird species regularly migrate, so they need to be well adapted for long flights

© Wiki

Soar like a bird

Many of the natural qualities of bird flight have inspired aircraft designers, meaning that some aspects of the planes we travel on are based on birds' features. Observing and transferring bird flight traits has led to the application of light frameworks and streamlined shapes.

One of the main qualities that enhanced aircraft was the curved surface of birds' wings to create uplift. The Wright brothers, who designed the first aircraft, studied these animals before twisting the shape of their aircraft's wings to match those of birds.

Hummingbirds can hover in the same spot for extended periods of time. Micro-helicopters aim to mimic this skill, but engineers are still working on how to improve the rotor power to achieve this.


Hummingbirds use over 20 per cent less power to hover than helicopters

© Getty

© Getty

"Aspects of the planes we travel on are based on birds' features"

Taking flight

From takeoff to touch down, how have birds perfected the art of flying?

Preparing for takeoff
When readying itself for a lengthier flight, a bird stores the required energy and builds up its flight muscles.

Lifting from the ground
Air flows quickly over the wings to create lift. Depending on leg strength, some launch from a standing position, while others need a running start.

Retracting the legs
It lifts its legs close to the body as they are not needed in the air. Doing this also helps to reduce drag.

Full upstroke
Wings are partially folded to remain streamlined. This stroke uses relatively little energy in preparation for the downstroke.

A bald eagle uses its large wingspan to glide through the air

5 FACTS ABOUT FLYING BIRDS

1 Weighty wings
Around a third of a bird's body weight is made up of the large wing muscles. These are the machines that power flight, keeping the bird airborne for large periods of time.

2 In a flap
Flapping is one of the most common flying methods, but it uses the most energy. Some birds alternate between flapping and gliding to conserve energy.

3 Hitching a ride
Taking advantage of the rising air thermals and updrafts, some birds soar in a circle around these areas to lift them higher, with minimal energy expended.

4 Mid-flight naps
Studies found that some birds can sleep while flying. Measuring electrical energy in the brains of great frigatebirds, results showed that they sleep in ten-second bursts during migration.

5 Furthest flyers
The Arctic tern has the longest migration of all the birds; over 80,000 kilometres a year. In their lifetime of around 30 years, their total flight distance is equal to three trips to the Moon and back.

The highest flyers

Rüppell's griffon vulture is the highest flying bird in the world, cruising at 11,000 metres in the air. Reaching the average flying height of a commercial aeroplane, these birds have evolved to carry a particular type of haemoglobin that absorbs oxygen more efficiently than in humans and other birds.

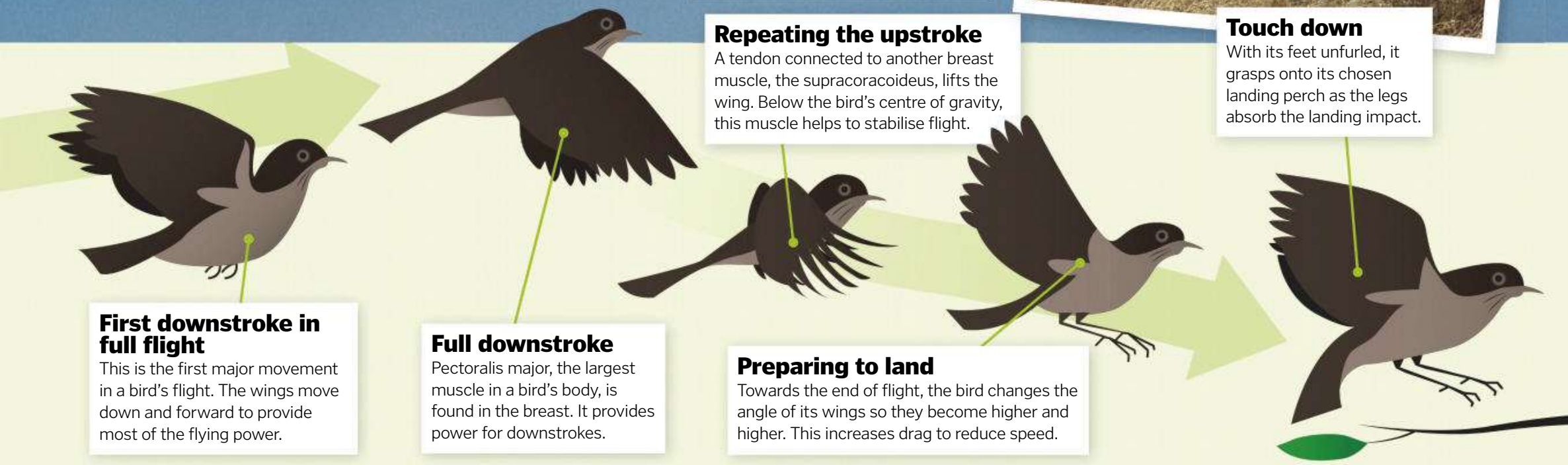
At great heights, these scavengers search for carcasses, their prime food source. These social birds can be found in their native home of Africa, nesting in colonies of around 200 birds, formed of pairs. They grow to have wingspans of 2.5 metres and can travel at speeds of over 35kph.


Flying near planes is dangerous. Griffon vultures have been known to be sucked into jet engines

© Getty


The wings of flightless birds, such as ostriches, have been repurposed for balance

© Wiki



First downstroke in full flight
This is the first major movement in a bird's flight. The wings move down and forward to provide most of the flying power.

Full downstroke
Pectoralis major, the largest muscle in a bird's body, is found in the breast. It provides power for downstrokes.

Repeating the upstroke
A tendon connected to another breast muscle, the supracoracoideus, lifts the wing. Below the bird's centre of gravity, this muscle helps to stabilise flight.

Preparing to land
Towards the end of flight, the bird changes the angle of its wings so they become higher and higher. This increases drag to reduce speed.

Touch down
With its feet unfurled, it grasps onto its chosen landing perch as the legs absorb the landing impact.

TRACTOR EVOLUTION

How farming has gone from horse-pulled carts to the tractors of today

Words by **Ailsa Harvey**

Tractors became popular in the US, where huge amounts of land needed to be worked

Tractors have been around since the 1800s, when John Froelich incorporated the first stable petrol-powered traction motor. For most people, the only experience of tractors may be driving behind one as it bounces along a main road, seemingly out of place. However, for those following the farming lifestyle, tractors represent huge progress in making farm work more efficient, by reducing the need for extensive manual labour.

The first tractors travelled at just five kilometres per hour but signified the beginning of agriculture's transformation to speedier farming. These portable steam engines, designed specifically for farming, emerged in 1868. As they became more widely available, the horses that farmers had relied on to pull weight since the early days of agriculture were made redundant. The tractor that replaced horses were monsters, weighing over 15 tons. These vehicles were mainly used for transporting large amounts of timber.

Following the tractor's evolution from steam to petrol-powered engines at the end of the 19th century, a man called Henry Ford (founder of Ford Motor Company) decided that simple tractors needed to be on the market for the "common person." Tractors had adopted many new features, such as self-laying tracks instead of wheels, but Ford brought them back to basics.


Tractors have revolutionised farm work across the world

© Getty

Naming his tractor the Fordson, it became the first lightweight, mass-produced tractor. As a more affordable model, farmers from different backgrounds could afford the purchase and join in the tractor trend.

1928 saw the release of the General Purpose Tractor. This model enabled farmers to work in volume, including planting and cultivating three rows of seeds at a time. The speedier and more efficient process that farming was becoming led to manufacturers aiming even

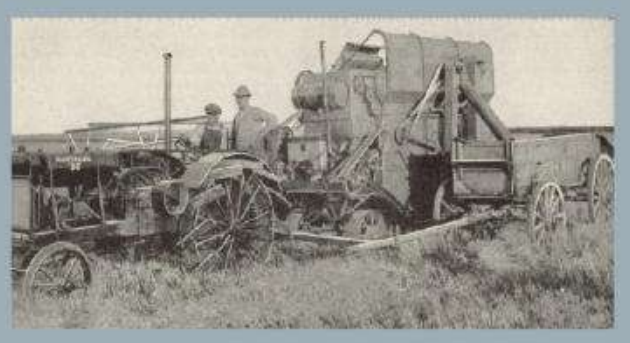
"The steam-powered tractor was still in use into the 20th century"

Driving away from steam engines

While attending university in the late 1800s, mechanical engineers Charles Hart and Charles Parr undertook research on petrol engines – studies that would soon turn the university friends into business partners.

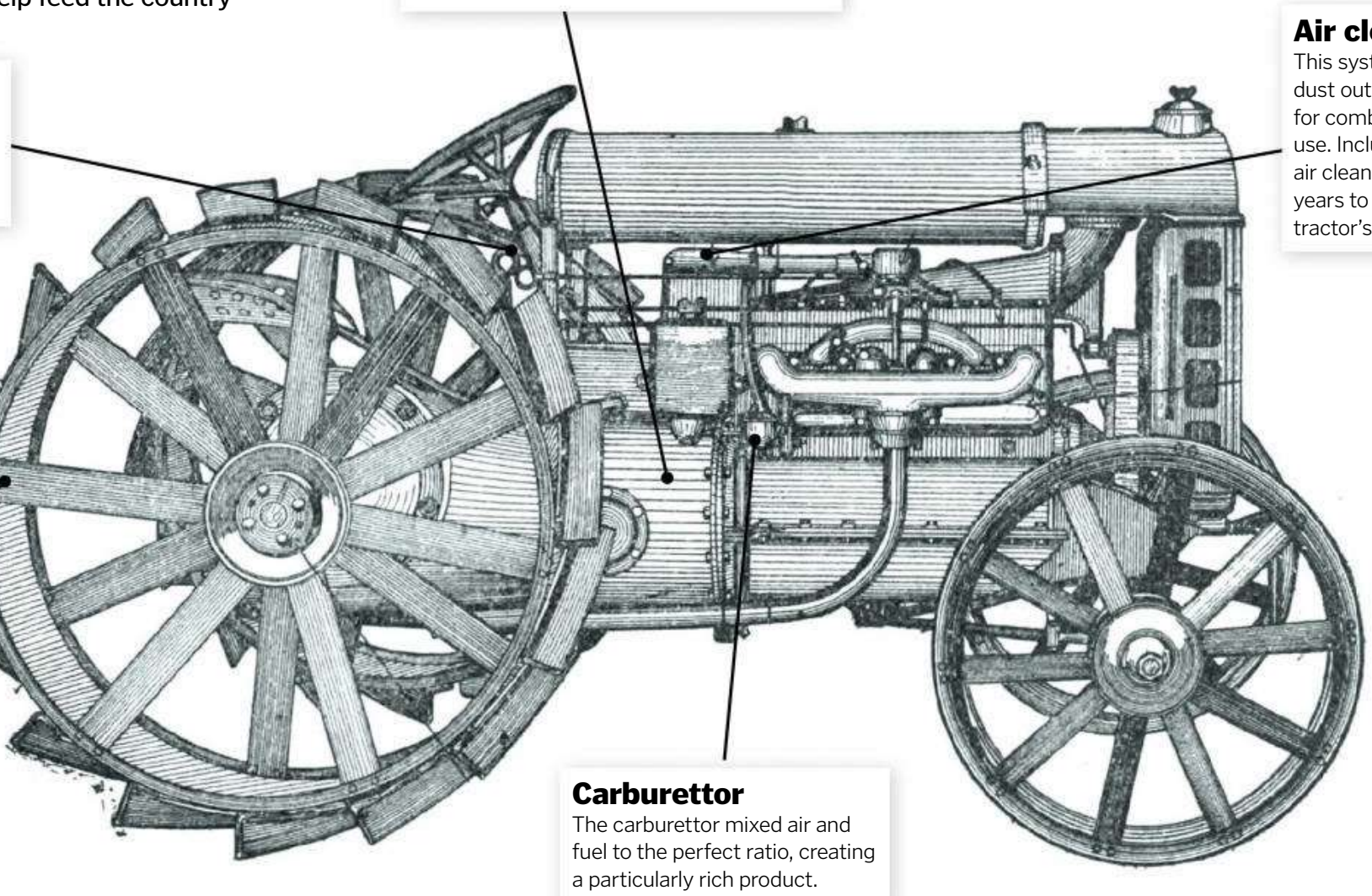
Together they started up their new company, called the Hart-Parr Gasoline Engine Company, creating the first factory in the US dedicated to petrol traction engines. As the pioneers of modern tractor manufacturing, Hart and Parr are considered the industry's founders. They were the first people to refer to these vehicles as 'tractors' rather than traction engines.

It was only after 1910 that tractors were used extensively in farming, their new engines transforming what they could do in terms of power and efficiency. Now tractors come packed with over 500 horsepower. Back then, however, the Hart-Parr tractors were greatly respected for exceeding 40 horsepower. Tractor manufacturing continued to improve models, making vehicles better adapted to their agricultural uses.


A Hart-Parr tractor being used in the 1900s

The Fordson

The compact and affordable Fordson was popular during and after World War I, when tractors were desperately needed to help feed the country



Four-cylinder engine
The engine burned a variety of fuels, but this was mainly petrol or kerosene. Beginning in the smaller tank for a few minutes, fuel moved to the larger tank once it had warmed, and generated 20 horsepower.

Cheaper design
The tractor had no separate outer frame. This made the vehicle more affordable as well as being lightweight.

Air cleaner
This system filtered dust out of the air for combustion use. Including the air cleaner added years to the tractor's engine life.

Rear wheels
The wheels were made of fabricated steel. The rear wheels were larger to improve traction.

Carburettor
The carburettor mixed air and fuel to the perfect ratio, creating a particularly rich product.

Powering through history

1878
Some of the earliest field engines emerge in the mid 1800s. The Eclipse farm engine by Frick is one of the first portable steam engines used.


© farmcollector.com

1882
The Harrison Machine Works portable traction engine is the first engine to be used around British farms.


© Bill Whittaker - vintagemachinery.org

1892
The John Froelich tractor is the first successful petrol-powered engine that can be driven backwards as well as forwards.

1903
Hart Parr number 3 is the oldest surviving tractor with an internal combustion engine.

1918
The kerosene-run Waterloo Boy tractor proves extremely popular among farmers, at a time when there are nearly 100 tractor manufacturers. Waterloo Boy is both cheap and multi-purpose.

1921
Ford Motor Company's ability to mass-produce vehicles means that over 25,000 Fordsons are imported to the Soviet Union alone between 1921-1927.


© newhollandag

1923
The John Deere Model D has a two-cylinder kerosene engine that produces 15 horsepower. This design brings versatility.


© John Schanlaub

1948
The Allis-Chalmers WD model brings groundbreaking features, including two-clutch power control, single hitch-point implements, traction-booster and power-shift wheels.


© Jimduell

1961
Merging tractors with aircraft development, International Harvester takes inspiration from its subsidiary Solar Aircraft Company, coming up with the HT-340. It carries a turbine engine that, while small, can turn 57,000 times every minute.

1986
The Massey Ferguson 3000 series sets new standards for tractors in terms of technological innovation. This model comes with advanced electronic controls.

2019
The Valtra N 154e Versu boasts improved suspension, agility, grip, balance and eco-friendly properties, including the addition of an eco-mode to reduce fuel consumption by 10%.


© JWH

AI in agriculture

Artificial intelligence is taking farming to new levels of sophistication. Platforms such as John Deere's Taranis enable fields to be monitored with less focus on human interference. AI platforms can assess the crop quality and incoming weather forecasts.

GPS within tractors is a step towards driverless controls. These and other new features mean that in the future machinery could tackle harvesting alone.

One of the benefits of this new technology is that it cuts down the extensive hours farmers are currently working to keep their fields on track. If they have a way of monitoring their grounds without constant patrol, the process becomes more efficient. Recent studies show that driverless vehicles require only ten per cent of the process' original supervision.


© Getty

GPS on tractors could lead to an automated farming future

higher, inventing new methods and designs to increase the productivity of tractors.

The John Deere Model R, a diesel tractor released in 1949, introduced a significant increase in horsepower. It was the first tractor to achieve more than 40 horsepower, but this wasn't the only improvement to the standard tractor model. In the late 1930s tractors made the change from steel wheels to rubber, but there were initial concerns from farm workers about this potentially weaker material. However, the gamble was rewarded: the substantial ribs in these new tyres gave better traction across the soft terrain, and this innovation can still be seen in the tracks of the thousands of tractors that roam today's fields.

Since the first tractor over 150 years ago, this metal workhorse has become more diverse and widely used, with a tractor for every farming need. The tractor has given farmers a means to continue an ancient practice far more efficiently, to help them meet the modern world's increased demand for food and materials.

"This metal workhorse has become more diverse and widely used"

Driving in darkness

Lights surrounding the tractor enable farmers to continue working after the sun goes down. These lights provide 34,400 lumen lighting power.


© Casieh.com

Driverless vehicles are the next stage in the evolution of the tractor

The Magnum

Creating the ultimate farming experience, the Case IH Magnum 340 combines superior comfort, manoeuvrability and modern-day digital farming assistance

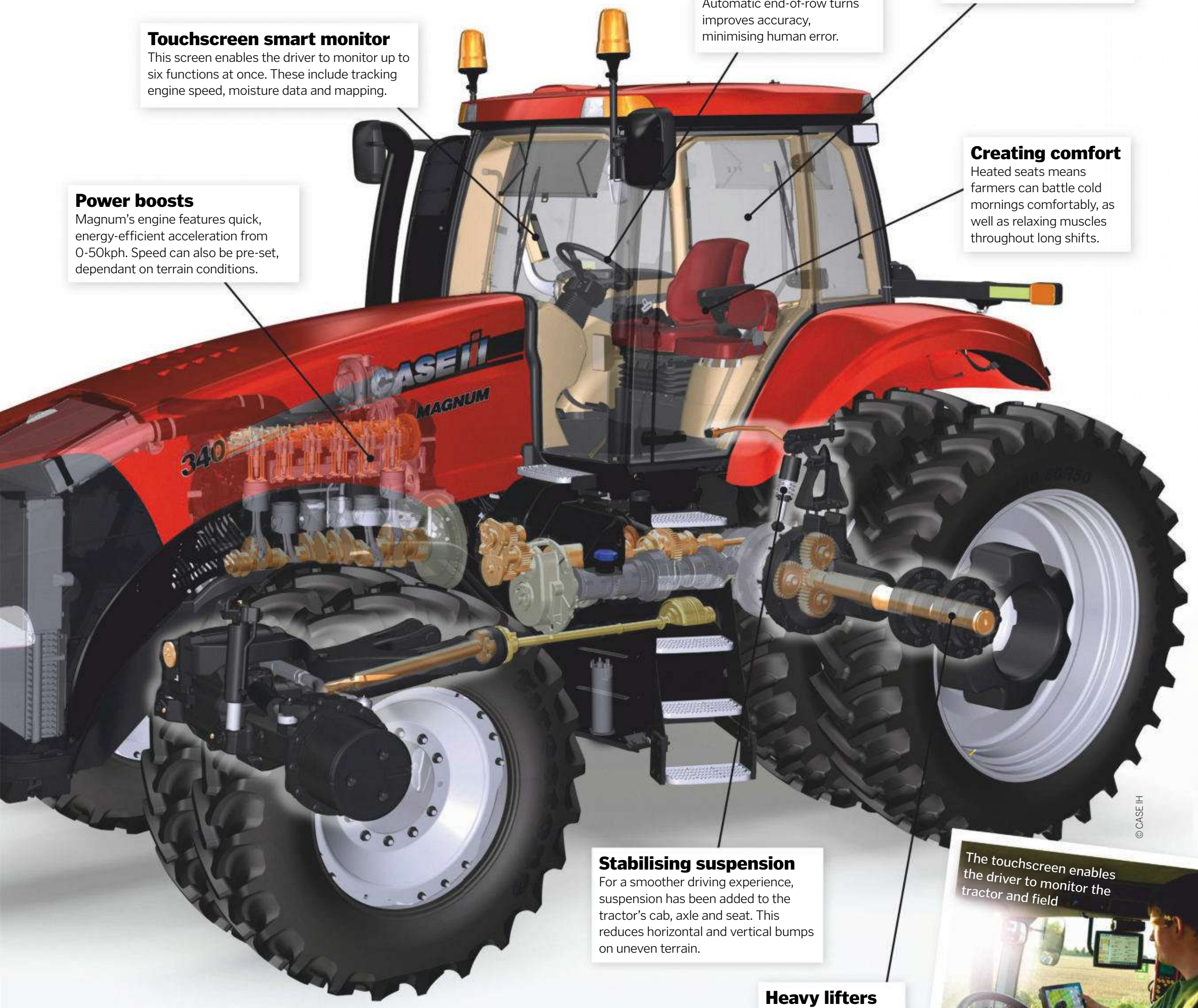
Touchscreen smart monitor
This screen enables the driver to monitor up to six functions at once. These include tracking engine speed, moisture data and mapping.

Automatic steering
The tractor's auto-guidance system is the next step to fully-automated farming. Automatic end-of-row turns improves accuracy, minimising human error.

Increased visibility
The six square metres of glass provide visibility across the whole field from any position.

Power boosts
Magnum's engine features quick, energy-efficient acceleration from 0-50kph. Speed can also be pre-set, dependant on terrain conditions.

Creating comfort
Heated seats means farmers can battle cold mornings comfortably, as well as relaxing muscles throughout long shifts.



© CASE IH

Stabilising suspension
For a smoother driving experience, suspension has been added to the tractor's cab, axle and seat. This reduces horizontal and vertical bumps on uneven terrain.

Heavy lifters
Transportation around the workplace is crucial. The lifting arms can pull up to 5,000kg.

The touchscreen enables the driver to monitor the tractor and field

© Getty

1/3
More than a third of the total cost of a tractor is spent on fuel

75%
Tractors bought in 1923 that were Fordson tractors, made by Ford

2.4 metres
The height of tyres on 'Big Bud', the world's largest farm tractor

72%
Over 70 per cent of the UK's land was used for agriculture in 2017

100
The number of people needed to do the work of one large tractor

Next stop: electric buses

How Volvo's new e-bus could help the planet and tackle traffic – all without making a sound

Transport makes up a quarter of the world's carbon emissions, with buses producing an average of 822 grams of carbon dioxide per kilometre. This is one of the leading factors inspiring the innovation of electric transport and the rise of the e-bus.

Volvo is a leading motor company that aims to provide cities with a more sustainable, efficient solution to bus travel. Eliminating harmful climate emissions is the main advantage of this electric bus system, but the Volvo 7900 Electric shows the potential for transforming journeys as we know them if all buses become electric.

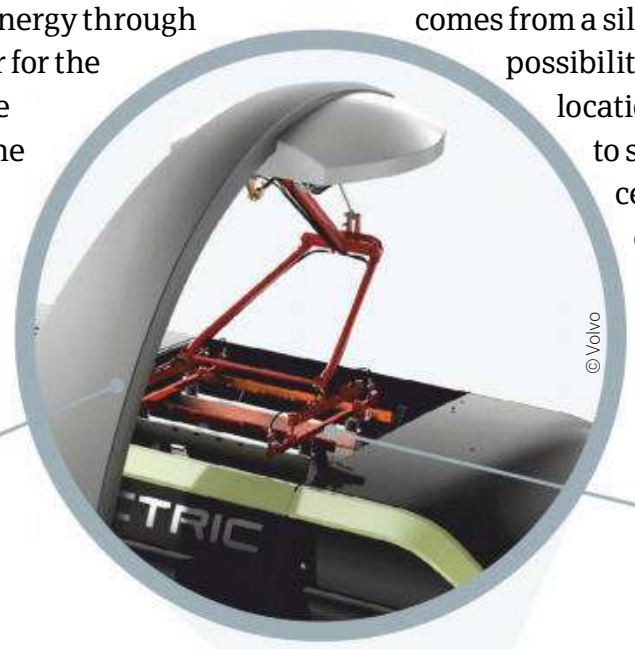
Bypassing petrol stations, electric buses can charge throughout their journey with stations at every bus stop, enabling automatic charging whenever the buses pick up or unload passengers. Named 'Opportunity Charging' due to the e-bus's ability to charge whenever it is near a station, this method is more energy-efficient and cost-effective, removing the need to divert individual buses from their routes.

Creating the required energy through battery charging is kinder for the planet, but what about the people who will occupy the seats inside? These buses aren't purely a benefit to the environment, but they can also make your commute a more pleasant experience, as the e-bus makes far less noise, provides a smoother journey with no engine vibration, and has a higher focus on interior ergonomics than older, petrol-fueled buses.

The potential for bus routes could also be much greater. The lack of disturbance that comes from a silent electric vehicle opens up possibilities for new bus stop locations. Soon you may not have to step outside a shopping centre to catch the bus, as the discrete rides could stop at indoor locations with minimal disruption.

Stop and charge

Volvo's Opportunity Charging System can turn every bus stop into a charging port

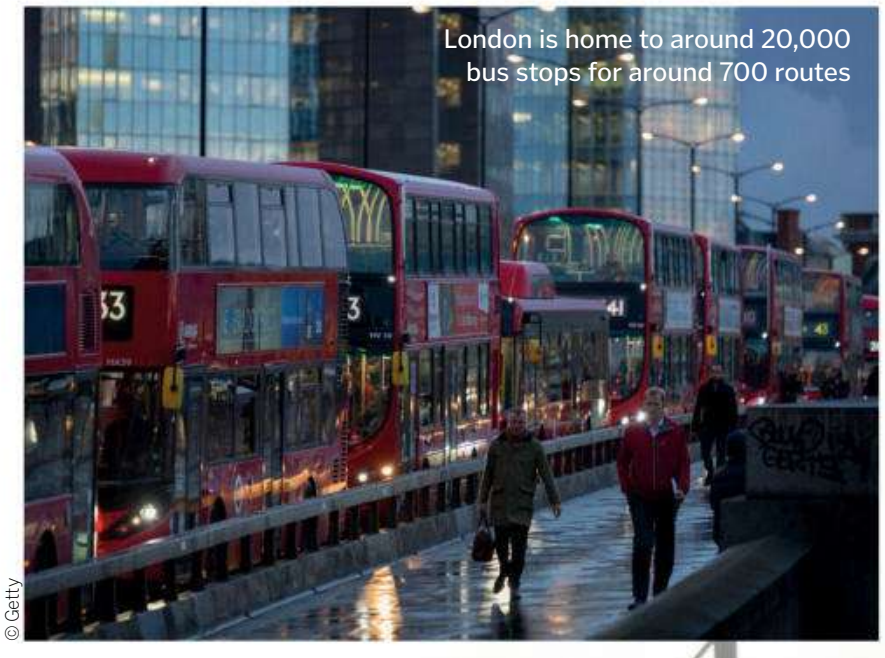


Pylon
The pylon carries the energy to the vehicle for charging. Full power will be achieved within six minutes.

Pantograph
The charging contact device is placed on top of the bus, the safest point of contact. If charge is lost, this device is able to move upwards on a spring.

Automatic charge
The bus automatically begins charging once it has stopped in the right position at the charging point, and ends when the bus is fully charged or departs.

Safe storage
The majority of electronic appliances are kept out of the way in a large cabinet. For safety reasons these devices remain concealed within housing.



London is home to around 20,000 bus stops for around 700 routes

© Getty

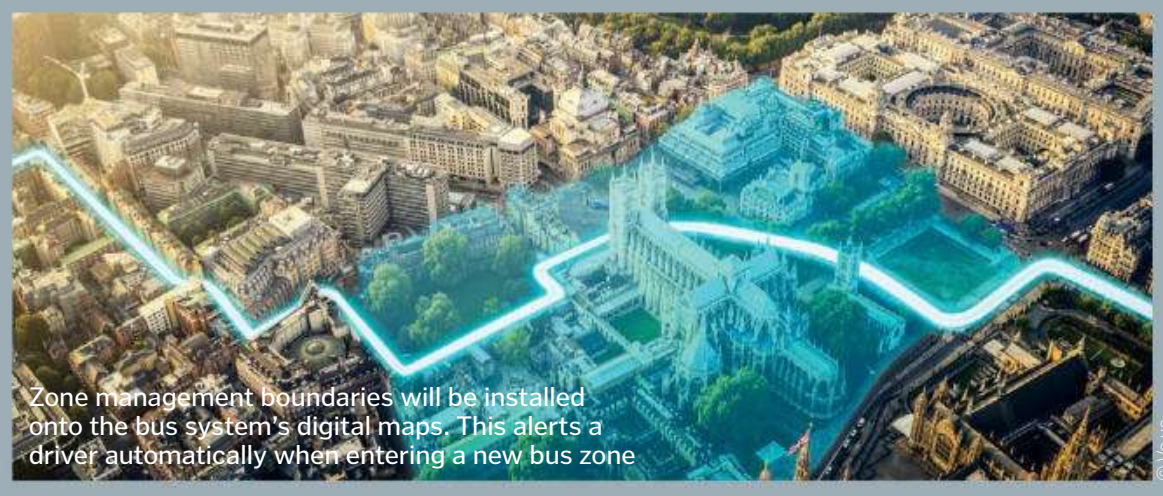
"Driving modes are tailored to suit specific locations"

Zone management

People require buses in a range of areas, and sometimes the intrusion of a large, noisy bus hurtling quickly along the roads can be disruptive. They have been known to create problems for residents, due to traffic and pollution.

Electric bus services could combat these issues by introducing a zone system in towns and cities. This system opens up a whole host of possibilities for public transport in the future.

The zone management means that vehicles need to comply with the rules allocated to each geographical region. Zone types include different speed limits to suit the area, silent zones near residential areas, zero-emission zones, preventing non-electric vehicles from entering, and safety zones that can report vehicles exceeding the speed limits. The buses will be equipped with zone-specific driving modes, such as those producing quieter driving, tailored to suit the different regions they will be driving through.



Zone management boundaries will be installed onto the bus system's digital maps. This alerts a driver automatically when entering a new bus zone

© Volvo

Underground connection

A system of underground cables connects the bus stops to the electric cabinets.

Controlling congestion

City centres such as London are renowned for their chaotic roads and stand-still traffic. With measures being put in place to create smoother vehicle flow around busy cities, e-buses aim to contribute to this progression.

The introduction of improved buses in itself is one step to reducing the traffic volumes in larger cities. With the comfort and safety of electric buses, people may become more inclined to travel on them. This reduction in private car use will help condense traffic queues through more efficient road use.

Not only this, new systems put in place in specific areas which limit emissions, noise and speed, through the e-buses' interlinked system, means that the number of vehicles able to withhold these driving conditions will be slimmer.

Opportunities to take routes never taken before will distribute public transport more evenly across roads. The ability to drive while creating such little noise means that quieter areas could be occupied for certain routes, whereas before they would have to take the main city centre roads like everyone else.

5 FACTS ABOUT ELECTRIC VEHICLES

1 Early electric vehicles
The first practical electric vehicle was invented in 1884 by Thomas Parker. His inspiration for the eco-friendly vehicle came from seeing the pollution around London.

2 The country leading electric
China has taken the lead in adopting electric transport. Last year more than 55% of the world's electric vehicles and 99% of electric buses were bought in China.

3 Looking ahead for London
London aims for all 9,200 of its buses to be emission-free by 2037. It now has over 200 electric buses.

4 Too quiet?
Regulations state that vehicles must make a noticeable noise when travelling below 30kph. Electric vehicles are seen as a risk when travelling at low speeds because pedestrians can't hear them.

5 Indonesian bus trials
The world's largest bus system is now trialling e-buses. Buses in Jakarta carry 200 million passengers each year, adding to one of the world's most polluted and congested cities.

© Volvo

WIN! A 3D PRINTER

This month we're giving away an MP Voxel 3D printer that lets you bring your three-dimensional digital creations into the real world, courtesy of monoprice.uk (monoprice.com)

For your chance to win, answer the following question:

James Bond '007' worked for which intelligence agency?

a) **FBI** b) **MI6** c) **CIA**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 GMT on 21 November 2019. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: www.futuretcs.com. Entries must be received by 00:00GMT on 27/11/2019. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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OFFER EXPIRES 31 Dec 2019

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?


JODIE TYLEY


TOM LEAN


LAURA MEARS


JAMES HORTON


JO STASS

More massive stars burn through their fuel more quickly and have shorter lives than smaller stars

Want answers?

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Is there an upper limit to the size of a star?

Xinyi Zhou

Astronomers believe the maximum size a star can grow to is 150 times the mass of our Sun. There are more massive stars, but they have been formed by two or more stars merging together. **JS**

© Pixelbay

Is there an animal that doesn't sleep?

Adrian Manson

This depends on your definition of sleep. Bullfrogs appear to have short periods of sleep throughout the day, but when scientists tested their responsiveness, they reacted just as quickly when they were asleep as when they were awake. This suggests they weren't technically sleeping but just in a state of rest. **JS**

© Getty

Who was Charles Darwin, and what did he have to do with the theory of evolution?

Brittney Graham

The British naturalist's theory of evolution explained how life adapts and diversifies over time. Darwin's revolutionary ideas were born out of a five-year voyage around the world in 1831, where he marvelled at the variety of similar species on the Galápagos Islands. In particular, he noticed that the beak shape of finches differed from island to island, each one suited to the foods that were available. Darwin suggested that the birds descended from a single ancestor and had evolved unique characteristics through natural selection – a process where the individuals best suited to their environment are more likely to survive and reproduce, passing these traits on to their offspring. **JT**

© Getty

How were books printed before computers?

Efan Irvine

Early printed books were made using a manual printing press. Each page of the book was 'typeset' by arranging metal letters, or 'type', into words and lines held in a flat frame. The type was inked and a piece of paper pressed down on top by the printing press to print the page. The pages would then be taken out, cut and sewn together to form books. Early printing presses were slow and hand-powered, but the technology became increasingly sophisticated as steam and electric power were introduced, and new ways of setting type and printing pictures were developed. **TL**

Can I get tired from thinking too much?

Jin Jun

Thinking does seem to decrease athletic performance. Scientists think it might be down to a chemical called adenosine, which builds up in the brain when we think. Adenosine makes us feel sleepy, but caffeine can perk us up again by interfering with the brain's adenosine receptors. **LM**

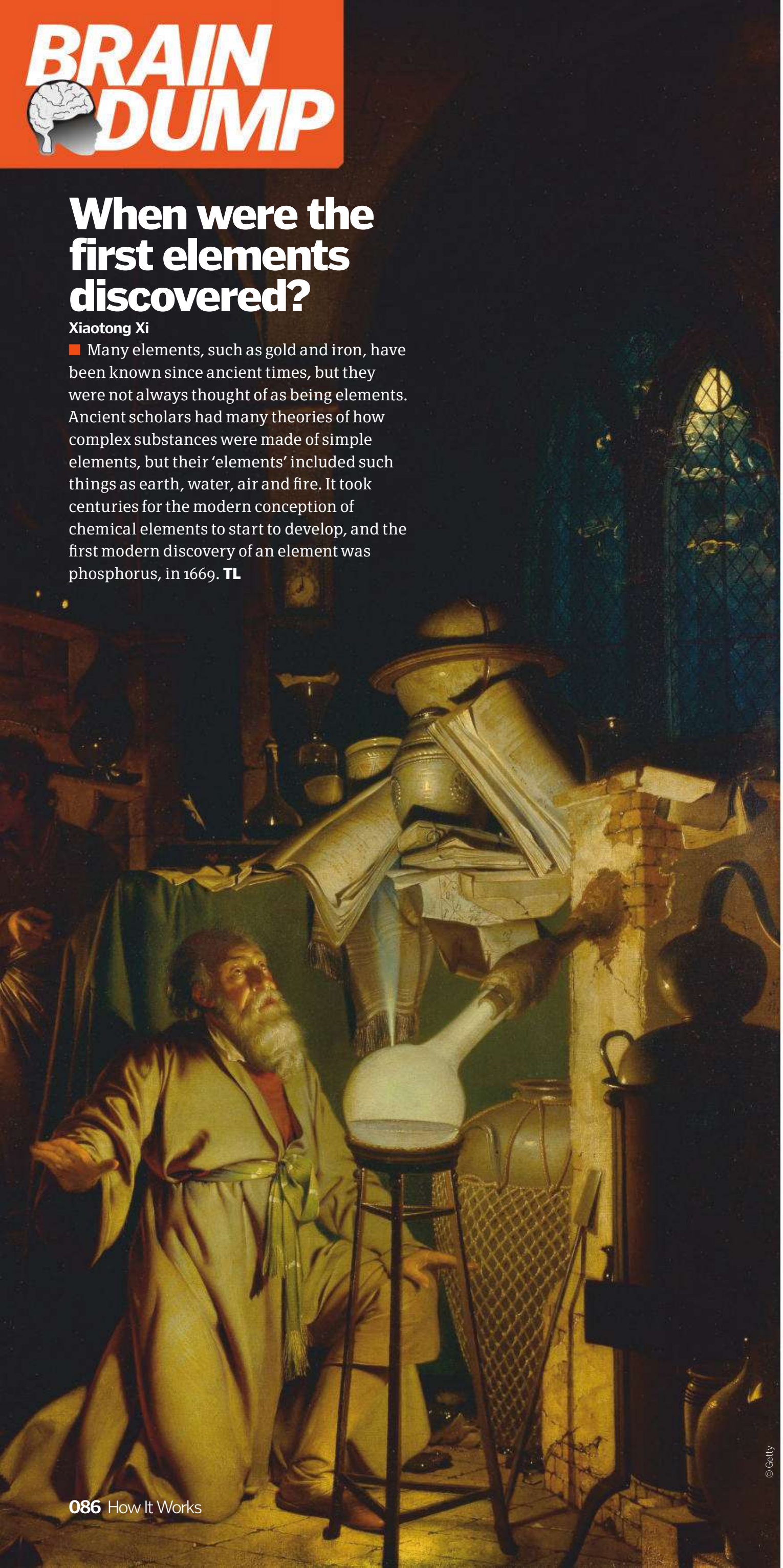
© Getty

BRAIN DUMP

When were the first elements discovered?

Xiaotong Xi

Many elements, such as gold and iron, have been known since ancient times, but they were not always thought of as being elements. Ancient scholars had many theories of how complex substances were made of simple elements, but their 'elements' included such things as earth, water, air and fire. It took centuries for the modern conception of chemical elements to start to develop, and the first modern discovery of an element was phosphorus, in 1669. **TL**



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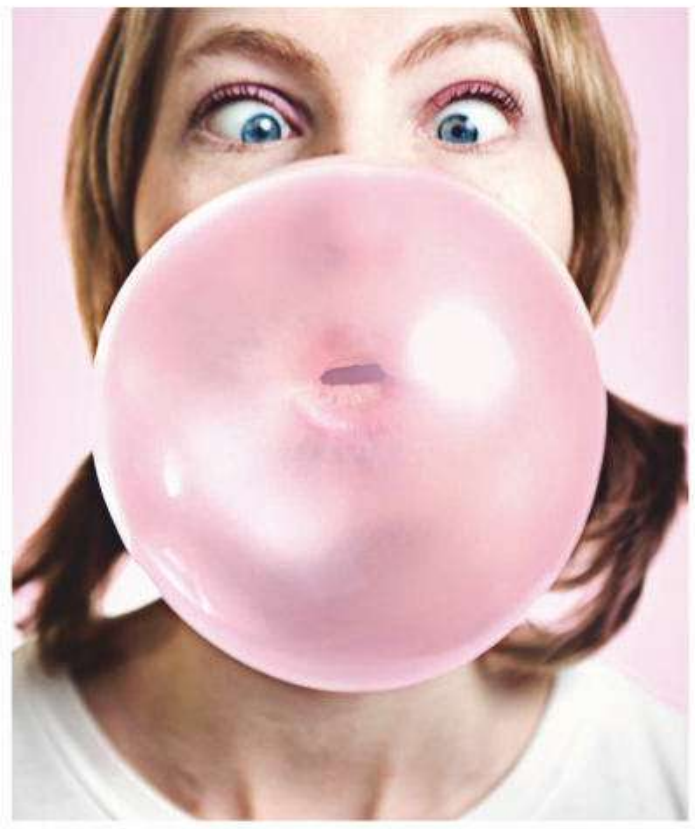

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How does chewing gum prevent tooth decay?

Alison Hortaleza Jones

Our teeth are coated in a thin layer of sticky bacteria called plaque, which feed on sugars from our food. Plaque bacteria turn these sugars into acid, which wears away at the enamel coating on the outside of our teeth. Over time, acid can make holes in tooth enamel, revealing the soft dentin underneath, but sugar-free chewing gum can provide some protection. The act of chewing increases saliva flow, helping to wash the acid and sugar away. **LM**

© Getty

Can you survive on bread and water alone?

Gianni Zola

It could be possible, but it's certainly not advisable. Humans have evolved to enjoy a varied diet so that our bodies get the nutrients we need, such as vitamin C to fend off scurvy and calcium to help build and maintain strong bones. Bread alone just doesn't cut it. **JT**

What was the Renaissance era?

Eduard Koch

After the Roman Empire fell in 476CE, the knowledge of ancient civilisations was lost and Europe entered the Dark Ages. The Renaissance, which began about 1300, was a great period of development that brought Europe out of the Dark Ages as advances were made in art, economy, literature, philosophy and other areas. **TL**

© Getty

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Can I catch anything from hair in my food?

Jonathan Howard

Although hair in our food is undeniably gross (especially in a bowl of cereal!) food safety bodies have found them to be safe. The microorganism staphylococcus – which can cause gastrointestinal problems in humans – can live in our hair and make us sick if eaten, but the likelihood of this is low. **JH**

What was the biggest nuclear bomb ever made?

Janet Foster

The Soviet RDS-220 hydrogen bomb, also known as Tsar Bomba, was detonated in 1961. It's believed to have been at least 50 megatons – 1,500 times more powerful than the bombs dropped on Hiroshima and Nagasaki combined. **JT**

© Getty

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Why aren't there more electric cars?

Richard Spencer

The key drive for electric cars has come from government incentives rather than consumers. Electric cars are climbing in popularity, but they're still typically expensive, and consumers worry about access to charging stations. As more companies make electric cars, it will lower prices and increase the number of charging stations. **JH**

BRAIN DUMP

© Getty

Can I name a star?

Vera Teodóra

■ Many companies offer the chance to name stars, but these have no official basis. Instead, scientists use rather long-winded descriptive names for the majority of stars, which aid other astronomers in their research. **JH**

How do dentists stick fillings to teeth?

Saliha Nasim

■ If you are having an amalgam filling (a mixture of silver, tin, zinc and mercury) the dentist will drill undercuts or ledges into the tooth to keep the filling in place. For composite resin fillings (a mixture of plastic and fine glass particles) they will use an acid gel to create tiny holes in the tooth enamel that the resin can fill and stick to. They may also use a bonding material to ensure the filling is extra secure. **JS**

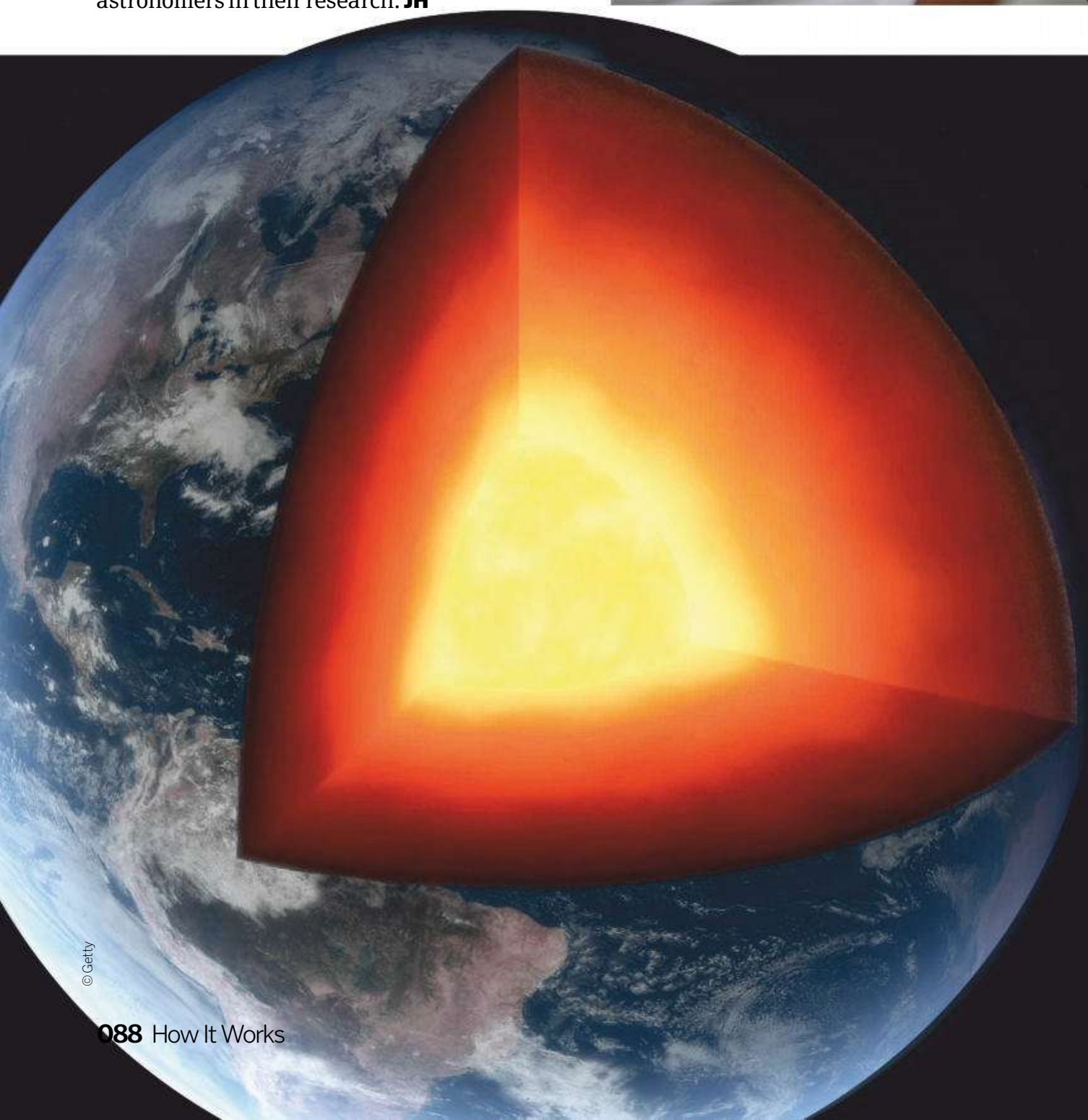
©Pixelbay

© Getty

Which fingers and toes are the most useful?

Juan Pablo Godofredo

■ Thumbs and big toes are by far the most useful digits. The most important function of the hand is the 'pinch grip' between thumb and finger. This ability is so critical that surgeons perform toe-to-finger transplants to restore a pinch grip in people whose fingers are missing. They often take the second toe for this, because we can still walk, run and jump without it. The little digits on our hands and feet are also very important for grip and balance. **LM**



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What would happen if I fell to the centre of the Earth?

Sayyid Raniya

■ If we were able to dig a stretch of tunnel that went straight to the centre of the Earth, jumping into it would spell immediate peril. Before you had even travelled one per cent of your journey, your body would be crushed by the immense pressure and scorched by the building heat. Then whatever remnants of you met the core itself would be completely incinerated. But let's pretend that we carved straight through the core and you are invulnerable to the other hazards. If that were the case, you would swiftly reach terminal velocity as you fell – about 200kph – and it'd take you just over a day of falling to arrive at the centre. Once there, you would be tugged by gravity in all directions equally, rendering you weightless – and also stuck there, floating forever! **JH**

© Wiki

Did King Harold really get shot in the eye with an arrow?

James Nelson

The last Anglo-Saxon king of England was killed during the Battle of Hastings in 1066, but no one knows for sure how he died. Early accounts didn't reference the weapon, and it was more than a decade later that mention of an arrow first appeared. The Bayeux Tapestry depicts men being slain with arrows and swords next to the phrase 'King Harold was killed', but we're not sure which figure was meant to be the monarch. **JT**

Will AI take over the world?

Efan Irvine

Currently the AI we have developed is only good for achieving very specific tasks, such as playing a game of chess or driving a car, and requires a great deal of human involvement. However, there is a very real possibility that in the future we could reach what is known as 'the singularity', where AI develops general intelligence and becomes smarter than humans. This would no doubt have a big impact on human civilisation, but there are several organisations, such as the Machine Intelligence Research Institute and the Future of Life Institute, focussing on keeping AI safe and beneficial for humans. **JS**

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Is global warming still reversible?

Edgard Solak

According to NASA, even if we stop emitting all greenhouse gases this second, the climate will continue to change. But it's not too late to limit the damage. **LM**

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Did William 'Braveheart' Wallace really exist?

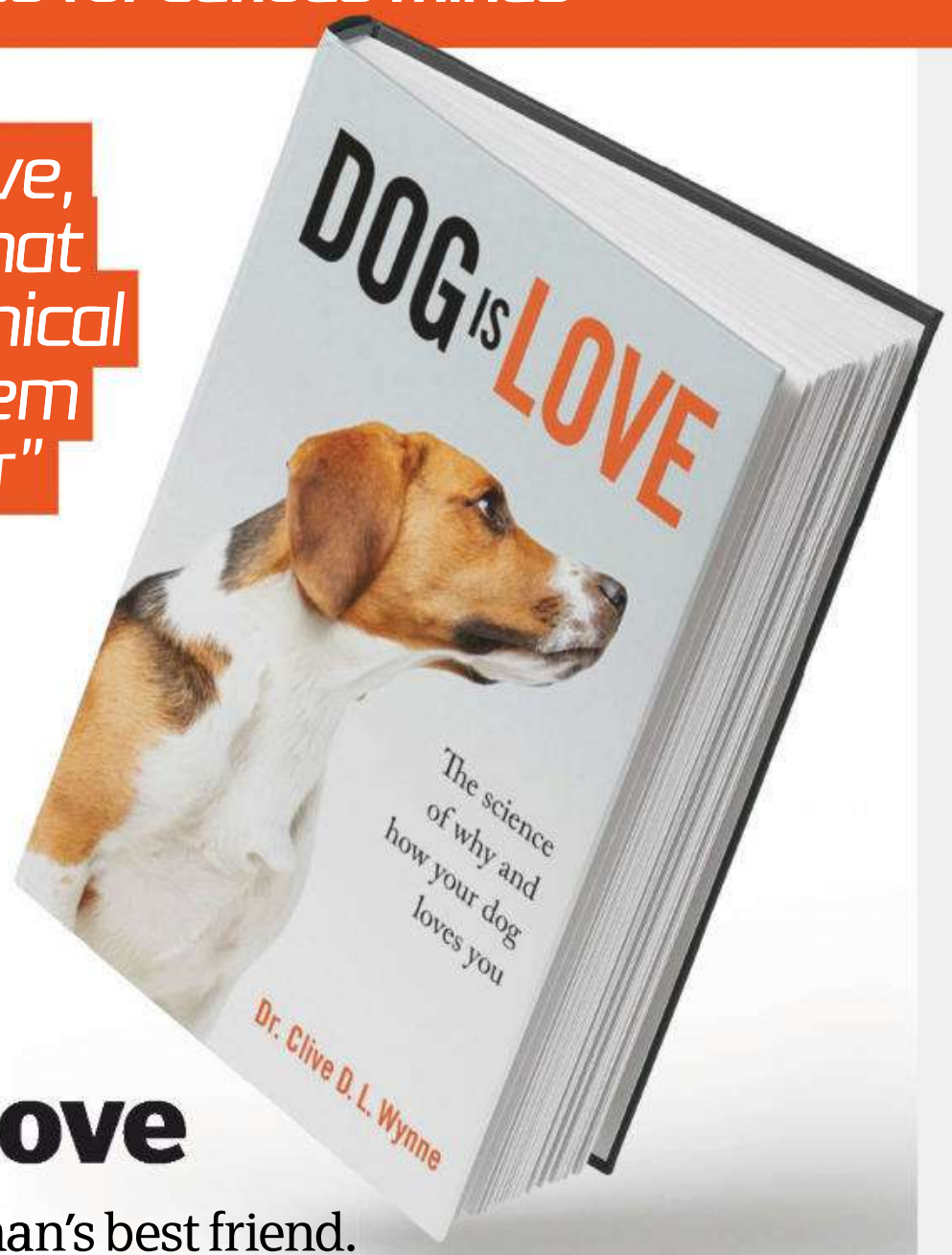
Jane Kemper

Wallace existed, but not quite like in *Braveheart*. Wallace was a knight and leader of the Scottish rebellion against the English. After losing in battle he went into hiding, but was later captured and executed. **TL**

BOOK REVIEWS

The latest releases for curious minds

"Dogs need love, and ignoring that need is as unethical as denying them food or water"



Dog Is Love

They say a dog is a man's best friend. Does science agree?

- Author: **Dr Clive Wynne**
- Publisher: **Quercus**
- Price: **£20 / $28**
- Release: **Out now**

Dog owners understand that the bond between them and their canine pal is unique and often unquantifiable. Unlike other animals, dogs are fiercely loyal and totally devoted to their owners – which is why they're often more than just pets. But how do we know whether a dog can truly love a human?

In *Dog Is Love*, Wynne strives to find out. Across a range of studies and stories, from behavioural analysis to evolutionary science and beyond, he explores the early relationships between wolves and mankind, the role of hunting dogs in human history, and the science of what goes on when a young puppy grows up around a human family.

The book opens with a personal account about Wynne getting his own dog, Xephos, in 2012. After explaining how she reacted when he first met her at the kennel, he uses this story as a launchpad to explore more about dog psychology. His prose is an easy mix of scientific investigation and personal insight – we learn as much about Wynne in these pages as we do about his research, which really helps you feel more involved and invested in his studies as you turn the pages.

It's clear from the first few lines that Wynne loves dogs, and his desire to showcase what makes canines so special shines out from the pages. As he explains in his introduction, dogs need love, and ignoring that need is as unethical as denying them food or water.

If you're a dog lover or if you have owned a pet, canine or otherwise, this book will hook you and keep you reading until you finish the final page. It's packed with interesting study, surprising insights and excellent tales of Wynne's interactions with dogs. The final chapter can be a tough read at times, as it explains the damage that cruelty or unkind training can do to an otherwise well-behaved dog. But there are plenty of positives too, such as Wynne suggesting kennels remove breed tags to help potential owners choose based on personality, and how it has helped more families to find the right pup for them. It's a good investment for current and prospective dog owners.

★★★★☆

Scientists Who Changed History

Meet the real superheroes

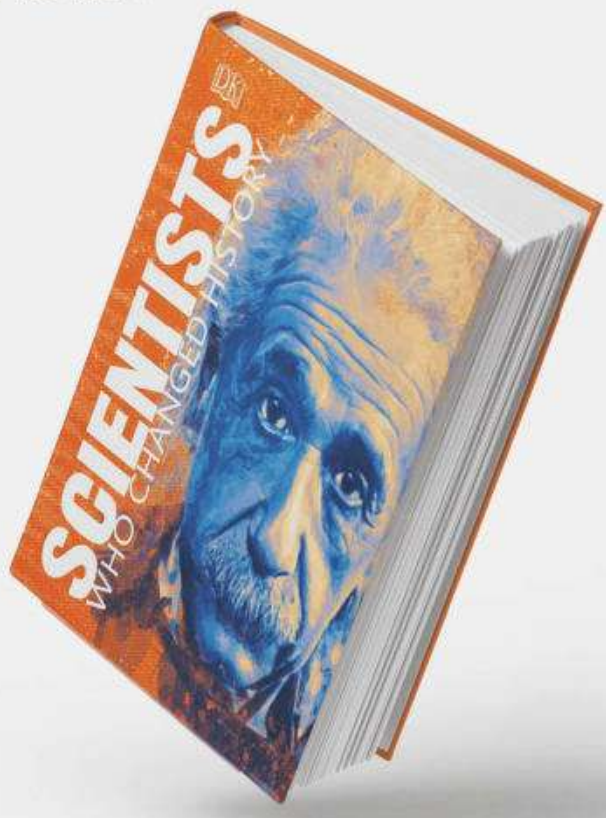
- Author: **DK**
- Publisher: **DK**
- Price: **£18.99 / $25**
- Release: **Out now**

The world is changing fast, and while it's the result of a team effort on the part of humanity, there are certain figures who command a larger share of the limelight. Not that it's undeserved. DK has decided to narrow things down, alighting on a very specific 88 individuals who have – and in some cases, continue to – leave their mark.

Taking a chronological approach, each figure is assigned a time period: from The Dawn of Science (650 BCE – 1450) to Theories of Everything (1950 – present), with the likes of Aristotle and Archimedes plotting a pathway through to Rosalind Franklin and Stephen Hawking. Each individual is given one to four pages – not enough for a complete breakdown of their accomplishments, but enough to chart the milestones and include noteworthy pieces of trivia. It's perfectly accessible for teenagers looking to gain a solid grounding in a who's who of science.

If you're looking for a complete biography of certain individuals then you're probably best advised to look elsewhere. But as a scientific primer, it's highly recommended.

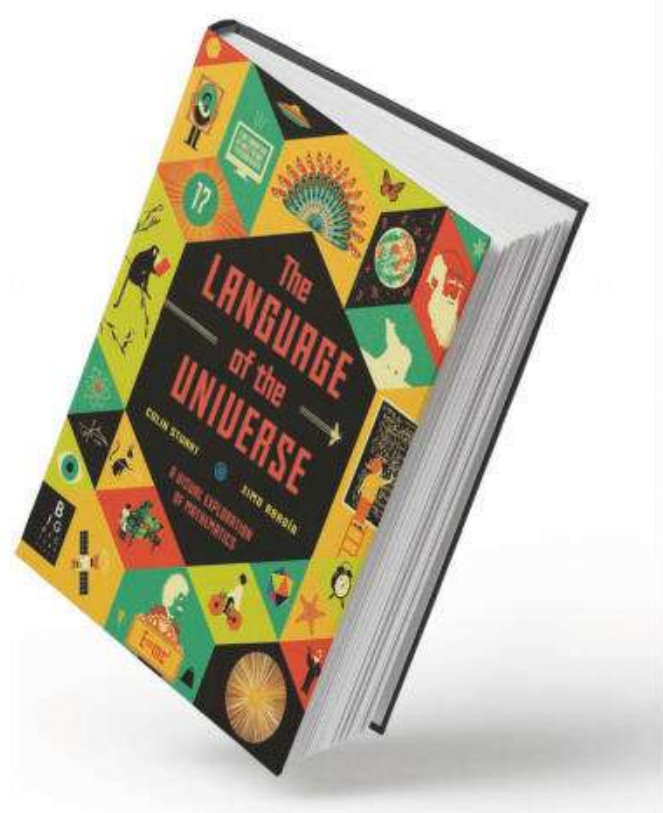
★★★★☆



The Language Of The Universe

Number crunching

- Author: **Colin Stuart**
- Publisher: **Big Picture Press**
- Price: **£16.99 (approx $20)**
- Release: **Out now**



Maths isn't always the most exciting of subjects, but it's easy to overlook just how important it has been to the development of civilisation. From trade and time-keeping to space travel, the subject has been a vital tool during humanity's growth, the case for which is made in this book.

Pairing the acclaimed surrealistic artwork of Ximo Abadía with the authoritative writings of Colin Stuart, the result is one of the most distinctive and evocative children's books you'll have seen in recent memory. Their approach is applied to how maths works in the natural world, swiftly followed by its role in our progressively more in-depth understanding of science, space and technology.

It's text-light, but that's ideal for its primary school target audience. Eye-catching illustrations are a tried and tested means of hooking readers in, and we can't imagine picking up a book bearing Abadía's drawings and stopping at just the one page.

We learned plenty of new things here, so it's a given that your budding young mathematician/astronaut/engineer will find their horizons broadened. The retail price is admittedly high, but don't let that put you off.

★★★★☆

Drastic Plastic & Troublesome Trash

Help save the world

- Author: **Hannah Wilson**
- Publisher: **Carlton Kids**
- Price: **£8.99 (approx $10)**
- Release: **Out now**

In light of the growing awareness of our negative impact on the planet and the recent global protests, the younger generations could be forgiven for wondering exactly what they can do to help. While this book doesn't have a definitive answer, it does provide some handy tips.

From reusing your old rubbish in an eye-catching way, to making things easier to recycle and revealing how to upcycle, there are a lot of tips here that may well come in handy. Exactly how effective this book is will depend on how willing to help the adults are, so be prepared to lend a helping hand (and provide some of the necessary materials).

The abundance of plastic lying around today is a pressing issue, and one that it's increasingly urgent to engage with. With the help of books and ideas like this, enough people might finally come on board.

★★★★☆

"The abaundance of plastic lying around today is a pressing issue"

Sean Yeager Hunters Hunted

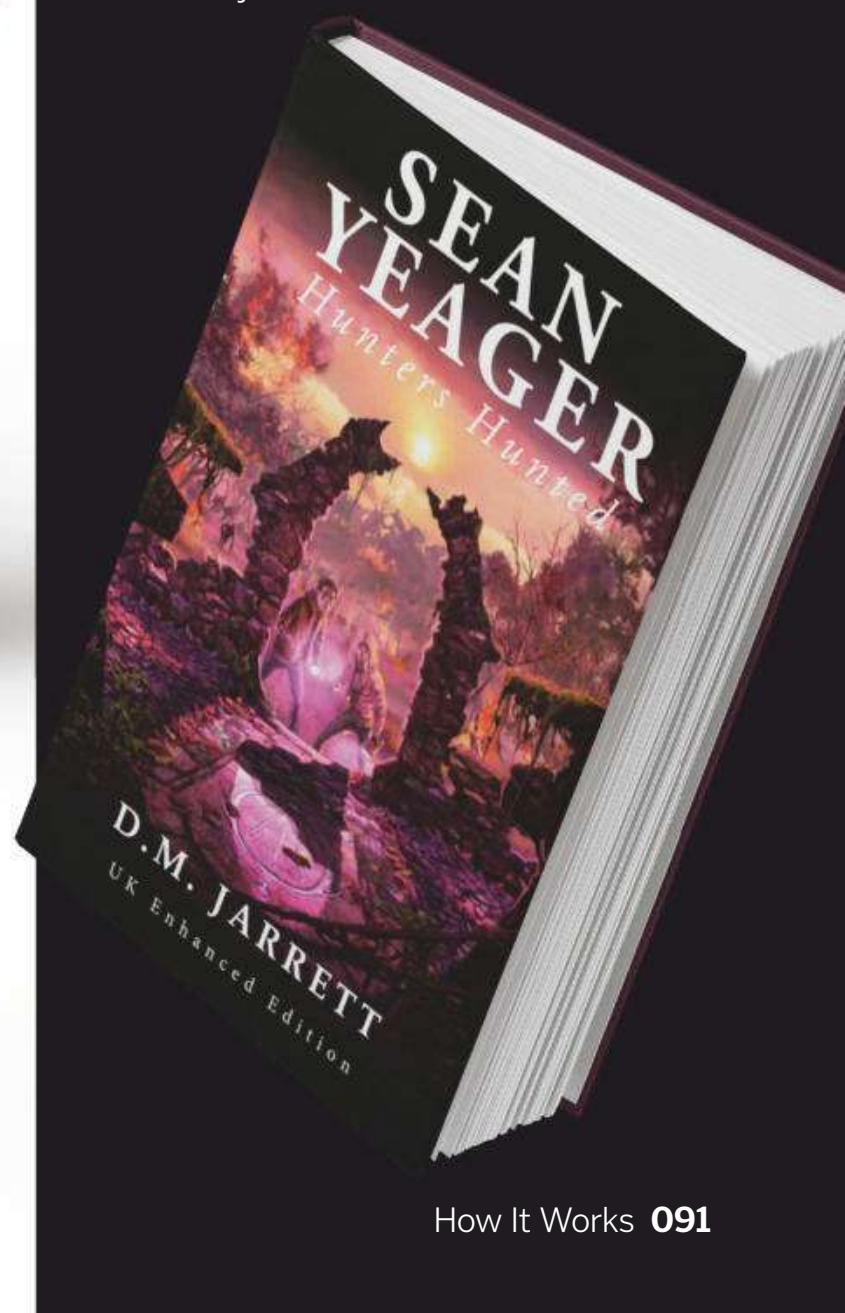
Time for adventure

- Author: **D.M. Jarrett**
- Publisher: **Aenathen Omega**
- Price: **£7.99 (approx $10)**
- Release: **Out now**

Sean Yeager Hunters Hunted is a fast-paced, science-fiction escapade written for ages 8–14. Sean and his mother are taken to a country safe house for their own protection, but Sean soon becomes bored. Mayhem ensues when he tricks his way onto a shopping trip to Yeatsford that goes explosively wrong.

On his return to Kimbleton Hall, Sean meets Emily, who cheers him up with tales of an ancient treasure rumoured to be hidden nearby. Together, they follow a trail of clues and explore Kimbleton Woods, not realising that danger is approaching from all directions. Sean and Emily must draw upon all their courage to stay one step ahead of their nemesis and complete their quest.

Hunters Hunted is the second book in the Sean Yeager Adventures series and is followed by *Claws Of Time*.



BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

X	P	D	M	D	P	V	I	R	T	U	A	L	Q	B
S	S	X	E	F	L	I	L	H	V	O	B	S	S	J
P	X	C	G	X	A	X	H	X	I	O	O	R	K	X
Y	G	A	A	X	N	X	W	X	C	S	C	D	X	D
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D	I	F	H	X	S	V	S	X	I	Y	X	O	I	S
R	X	L	R	O	O	X	S	X	A	A	W	S	H	S
O	M	A	T	S	T	T	I	T	N	S	I	T	Y	R
T	T	G	O	H	O	M	M	E	Y	E	X	T	I	A
C	X	E	R	Y	Y	L	E	L	A	E	R	M	A	M
A	A	T	P	R	I	N	T	E	R	T	H	E	R	O
R	B	V	X	H	S	S	O	D	D	R	I	X	T	X
T	X	Z	Z	X	H	X	T	E	L	X	L	O	Y	E

FIND THE FOLLOWING WORDS...

SPY
VIRTUAL
CAMOUFLAGE
PRINTER
SOVIET
VICTORIAN
TOTEM
GHOST
PLANET
EXOMARS
MEGALITH
TRACTOR

Quickfire questions

Q1 What does the 'S' in LASER stand for?

- Simulated
- Segregation
- Stimulated
- Separation

Q2 What year did work commence on the Berlin Wall?

- 1961
- 1071
- 2011
- 1945

Q3 Which of these is not a Mars rover?

- Sojourner
- Spirit
- Endeavour
- Opportunity

Q4 How heavy is the Australian sandstone monolith Uluru?

- 1,425 tons
- 14,250 tons
- 1.425 million tons
- 1.425 billion tons

Spot the difference

See if you can find all six changes we've made to the image on the right

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

2	1		8		5	3	7	4
					7			9
4		7					5	
7		6	1			9	3	5
3	8		9	4			1	2
9	2					8	4	
	3			7	2			
	9		3	8	1	6	2	7
	7				4			

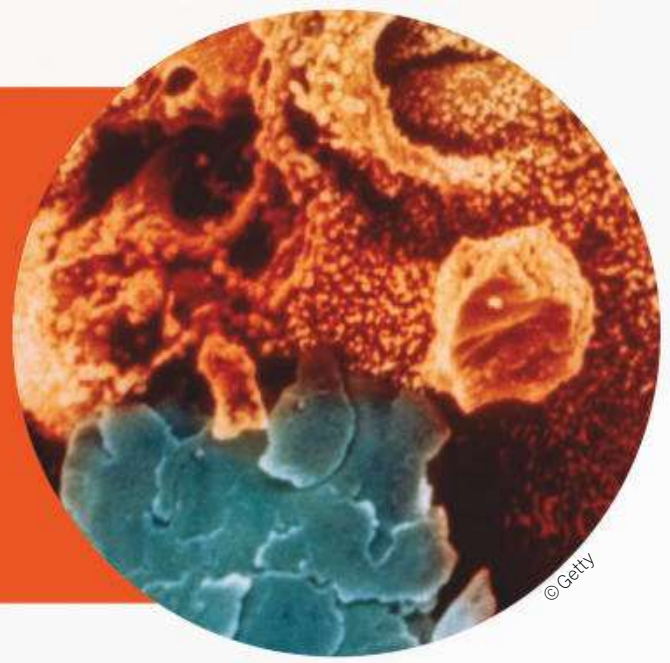
DIFFICULT

			2	8	7			
4			6	1				3
		8						
					8	2		
	4					1		
2		9			5			
	3				4	6		5
6	1						9	4
	5					7		8

What is it?

Hint: This is how we all began.

A .....



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Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

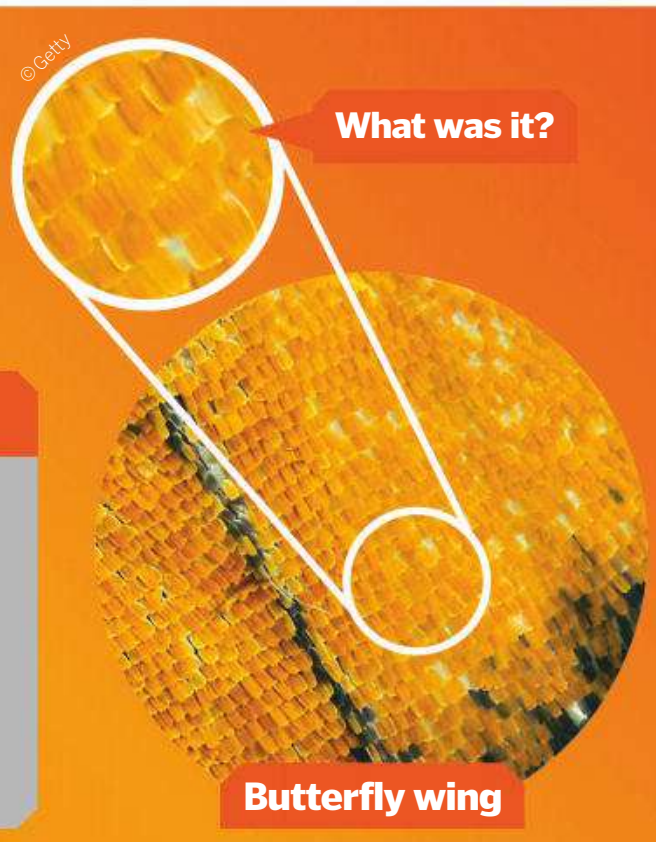
Q1 Lonsdaleite

Q2 40,000

Q3 100 billion

Q4 1883

What was it?



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Butterfly wing

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Turn milk into glue

Use a simple chemical reaction and some smart mixing to turn normal milk into natural glue

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

1 Heat the milk

First of all, measure out around 250ml of milk, then pour it into the pan and start to warm it – ask an adult for help if you need it. Then once it's warm, add three teaspoons of white vinegar to the saucepan.

2 Separate the curds

Continue heating the mixture, stirring it consistently as you warm it, until you start to see solids separate from the liquid. These are the solid curds separating from the liquid whey in the milk.

3 Strain the mixture

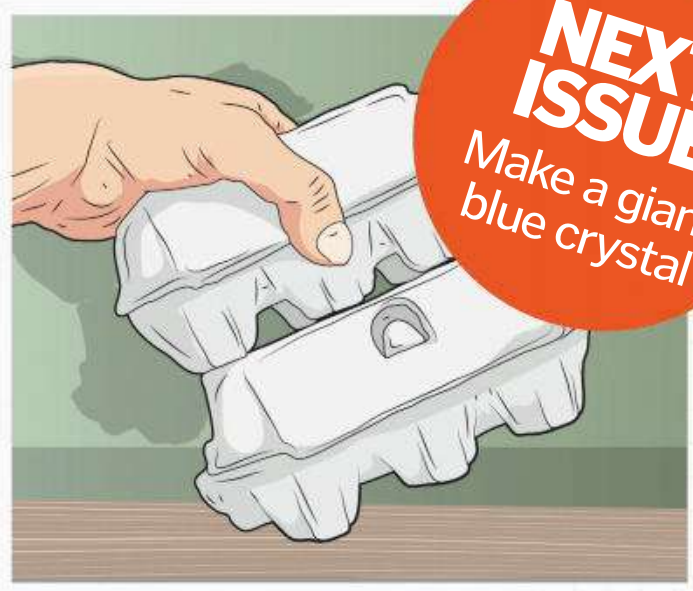
The vinegar causes a chemical reaction in the milk that forces the two substances to separate in the acid. Use a sieve to strain the mixture, then gather up the curds and mould them into a ball.

4 Add some water

Put the solid curds back into the pan and add a little water and a tablespoon of baking soda. Heat the mixture up again until it starts to bubble – this is carbon dioxide that's being released in the reaction.

5 Get the consistency

The bubbles are formed due to the reaction when the acidic vinegar is neutralised by the alkaline baking soda. You may need to add more water or baking soda to get the thick, paste-like consistency for your glue.



NEXT ISSUE
Make a giant blue crystal

6 Start sticking

Leave the mixture to cool. Now that the acid is neutralised, the curds can form back into a liquid again – they are made of milk protein, or casein. This is a natural glue, so test it out on some household objects!

SUMMARY...

Milk is a complex compound containing fat and proteins (including casein). When you add vinegar to the milk, it causes the pH to drop, and the negatively charged casein begin to attract other molecules to form lumps. This is called coagulation. When the alkaline baking soda is added, this neutralises the acid, allowing the molecules to separate again.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com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Seedy animals

Dear **HIW**,

Can seeds really grow on animals? I am a pupil from Shanghai, China.

Ada

Plants have various ways to distribute seeds, including transportation in the wind, being eaten with fruit and taken through an animal's digestive tract, or carried in an animal's fur.

While seeds can stick to the fur of animals, they only grow when they reach soil in a new location. These seeds are covered in hooks and spines to cling onto an animal and be taken somewhere where there's more room to grow.

Spores have been known to grow on animals, however, with moss found growing on the fur of sloths. This is because their fur has the perfect conditions and nutrients for the algae to thrive, creating green-tinted sloths.

Self-healing mats

Dear **HIW,**

I bought a rotary cutter and mat. How is it possible that the very sharp rotary cutter will cut fabric but not cut through the mat or leave visible cuts on the mat?

Lorraine Jones

When cutting fabric using a rotary cutter, the mat underneath is designed to remain intact. Some mats are 'self-healing'. They are made from lots of small pieces pressed together to make one solid surface. When you press the cutter through the fabric, the blade can go between these pieces, separating them, but doesn't cut the mat as a whole. The surface is then able to close back together instantly.


© Getty

Letter of the month

Weighing planets

Dear **HIW,**

How do we know planets' weights if there is no gravity in space?

Ethan Rochefort

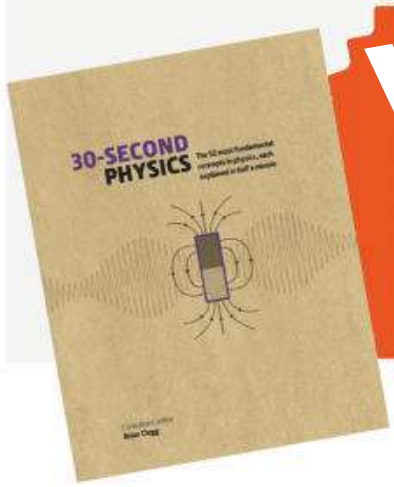
This is a great question for indicating some of the core differences between research here on Earth and throughout space. Some of the research into this question was carried out in the 1700s, but first let's look at how gravity is used to determine weight.

If we are measuring an object – let's say ourselves – we may stand on a weighing scale and use Earth's gravity to see how hard it is having to pull down to keep you on the ground. The mass of a planet is determined in a similar way. To measure the weight (or more accurately, the mass) of any celestial body, scientists need to look at how the planet pulls on other objects. The more massive it it is, the greater the pull will be on surrounding objects in space, such as moons or spacecraft.

Earth has a mass of 5,972,000,000,000,000,000,000,000 kilograms (shortened to 5.972 x 10^{24} kg). Henry Cavendish was the first person to work out a system for weighing the Earth in 1797. Cavendish measured the gravitational attraction between two different-sized lead spheres. The smaller spheres were suspended on either end of a wooden rod, while larger, heavier ones were placed near them. The gravitational attraction between the different-sized balls caused the rod to move from side to side. By finding the gravitational force between the two spheres, he could then relate the force to the larger sphere's weight to determine Earth's mean density and mass.

© Getty

The first ever calculation of Earth's density was within 1% of today's estimate



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NEXT ISSUE...
Issue 132 on sale **28 NOV 2019**

Sleepy bears

Dear **HIW**,
How do koala bears avoid being eaten if they sleep so much?
Oscar Tivendale


© Getty

Koalas sleep for over 20 hours a day, so they spend four hours or less at their most alert. Their eyes are shut for the majority of their lives, and koala bears actually have very poor eyesight when they do open them. This means they rely heavily on their other senses. It is their hearing that mainly helps them to detect danger, while their large noses help them familiarise with their surroundings.

Usually found sleeping high up in Eucalyptus trees, their position makes it difficult for animals on the ground, such as dingoes, to catch them. Koalas also have few natural predators. Deforestation is currently one of the biggest threats to their population.

An estimated 10 million pumpkins are grown in the UK each year, with 95% being carved for halloween


© Getty

Halloween history

Dear **HIW**,
Why do we carve pumpkins at Halloween?
Christian Howard

This is a question that many of us wonder about at this time of year, as the demonic pumpkin faces line the streets. These lanterns can be traced back to an old Irish myth about a man called Stingy Jack. After tricking the Devil on numerous occasions, Jack is said to have been punished by not being allowed into heaven by God and not being allowed into hell by the Devil. Therefore he was thought to be left to haunt the planet for eternity.

Lanterns resembling today's pumpkins were carved in Ireland to scare Jack away from people's homes. Originally carved from potatoes and turnips in Ireland, immigrants brought the tradition to the US, where pumpkins were readily available.

What's happening on... social media?

What piece of spy technology would you invent and what would it do?

@radders2012
"From my 5 year old: Teleportation so he can sneak up on baddies!"

@giddyypixie
"A literal "fly on the wall." A spy fly that could be directed to fly anywhere, to any location and listen in and film a 360° view."

@Colette
"GPS shoe tracker built into the sole. Resistant to water and smelly socks!"

HOW IT WORKS

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Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9001

ISSN 2041-7322

FAST FACTS

Amazing trivia to blow your mind

5,000

THE NUMBER OF PEOPLE WHO ESCAPED EAST GERMANY BY GOING OVER OR UNDER THE BERLIN WALL

500+ HORSEPOWER

THE BIGGEST TRACTORS MAKE LIGHT WORK OF THE TOUGHEST AGRICULTURAL TASKS

45.16 KM

THE TOTAL DISTANCE NASA'S OPPORTUNITY ROVER TRAVELLED AFTER LANDING ON MARS

$60,000

COMMISSIONING A TOTEM POLE FROM A SKILLED ARTIST CAN BE EXPENSIVE

18%

NEARLY ONE IN FIVE AMERICANS THINK THEY'VE SEEN A GHOST

IN WWI, GERMANY PUT UP A 7.5-METRE-TALL FAKE TREE IN NO-MANS LAND TO SPY ON THE ALLIES

40%

A CITY PIGEON'S PECTORAL MUSCLES ACCOUNT FOR A HUGE PROPORTION OF ITS TOTAL WEIGHT

13 BILLION YEARS

THE OLDEST OBSERVED PLANET FORMED JUST 1 BILLION YEARS AFTER THE BIG BANG

NASA HAS 3D PRINTED A PIZZA FOR ASTRONAUTS TO EAT IN SPACE

$20 MILLION

IN THE 1960S, THE CIA SPENT MILLIONS ON THE FAILED PROJECT 'ACOUSTIC KITTY' – SPY CATS WITH MICROPHONE IMPLANTS

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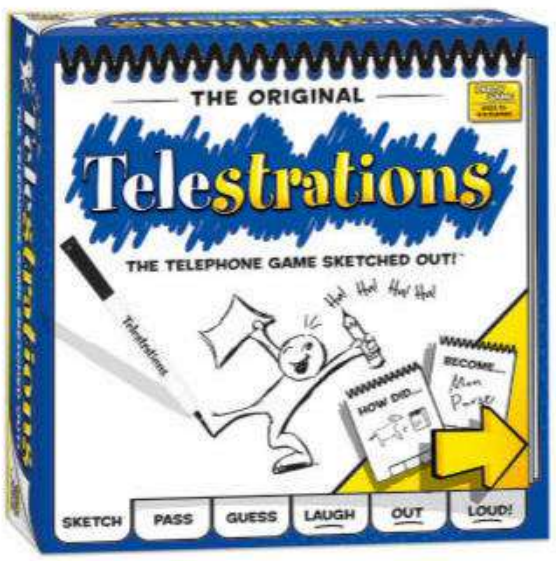

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